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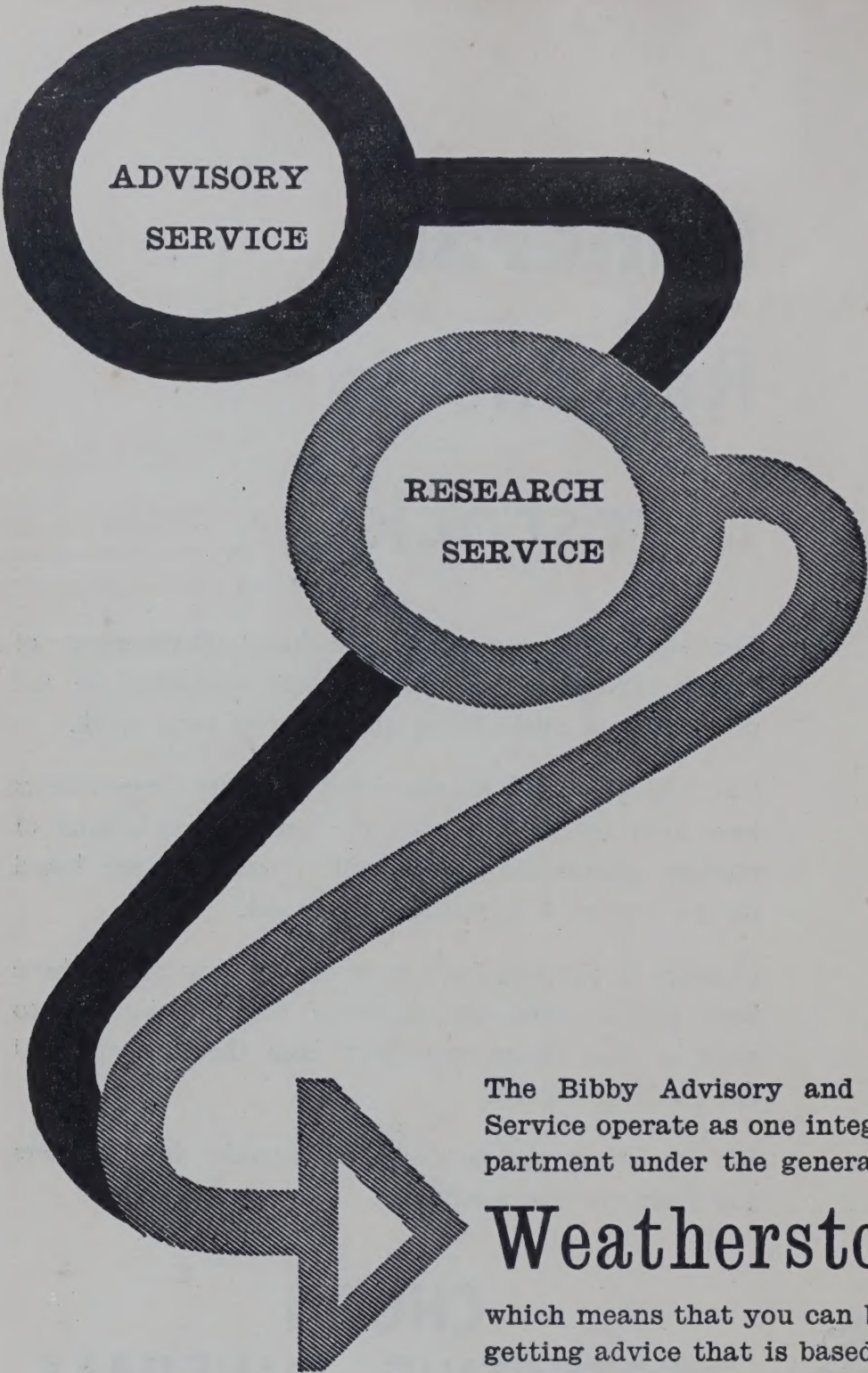


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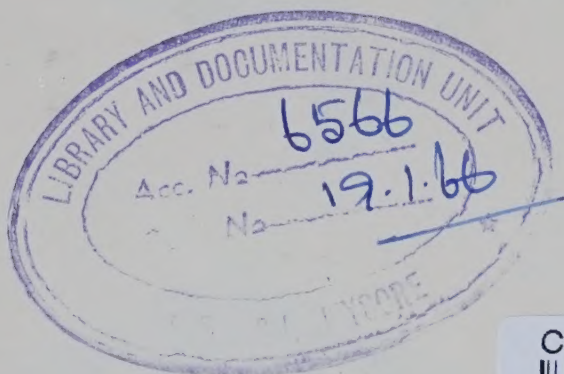
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Rations for live...

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Foreword

'RATIONS FOR LIVESTOCK' has a unique position in agricultural literature. Since its first appearance in 1921, when the late Professor T. B. Wood was the author, it has been the one publication that aimed at being complete — to give typical analyses and digestibilities for all the foods that farmers might feed to their livestock. Succeeding editions were prepared with characteristic care by Dr. H. E. Woodman, the fourteenth appearing in 1957 after his untimely death.

Certain major changes have been made in the present edition. The special section on rationing horses has been dropped, brief descriptions of the more common feedingsuffs have replaced the section on self-sufficiency on the farm, and separate tables of composition and digestibility are now given for ruminants and for pigs. It has been very difficult to decide on the extent of the introductory material preceding the tables. On the one hand, it was not intended to produce a text-book on animal nutrition and, on the other, enough had to be written to make the tables intelligible and to enable the reader to understand their use. The compromise adopted was to provide the basic information here and to leave further detail to specialized bulletins dealing separately with the different classes of animals (e.g., No. 10, *Calf Rearing*).

The Ministry is very grateful to those who have given freely of their time and have spared no efforts to make this edition worthy of its predecessors. Dr. R. E. Evans has been mainly responsible for the descriptive material, which he has largely rewritten. Dr. A. Eden's chief responsibility has been for the tables. For the latter, many new data have been used and Mr. A. Harvard, M.Sc., has spent much time checking and revising the figures. Mr. W. B. Mercer, C.B.E., has been general editor and has made valuable contributions in rearranging and clarifying certain sections.

H. G. SANDERS

Chief Scientific Adviser (Agriculture)

Ministry of Agriculture, Fisheries and Food

January, 1960

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Principles of Feeding

FEEDINGSTUFFS are composed of nitrogenous compounds called proteins and amides, of ether extract, which includes fats and oils with varying amounts of impurities dissolved by the ether in the process of extraction and estimation, carbohydrates, such as starch or sugars, which are called the nitrogen-free extractives, crude fibre, which may be valuable cellulose or useless lignocellulose, ash or mineral substances and of vitamins.

Proteins are the tissue or muscle-building components of the diet, hence the particular need of young stock for a dietary source of protein to build up its framework. The ash contains lime and phosphate, the bone building minerals which form the skeleton that not only gives the body rigidity but also acts as a storehouse of these two essential minerals. Other minerals, however, have equally vital functions to perform, and these will be described later.

Carbohydrates and fats are the main source of energy, and a given weight of fat provides 2.25 times the energy of the same weight of carbohydrate.

The crude fibre is important not only as a source of nutrient, but also for its physical effect in aiding mastication and promoting rumination. Indeed, the physical nature of the diet may in certain circumstances be as important as its chemical composition. A diet may be rich in all the food nutrients and yet prove unsatisfactory in practice because of its lack of bulk. On the other hand, a diet may be so bulky as to limit the amount of energy the animal can consume, even when eating to its full capacity. Bulk then becomes the limiting factor in determining productivity.

It is customary to talk of a balanced diet though the term is meaningless without reference to the animal to which it is to be fed. Thus a diet that is balanced for a calf is very ill-balanced for a mature animal.

Broadly speaking, the diet must provide sufficient bulk to satisfy the appetite, enough protein to repair the wear and tear of body tissues in maintenance, with a surplus that will suffice to produce new flesh in growth or as a source of milk proteins. It must supply enough energy for walking about, for the muscular activity involved in grazing, and to keep the body warm. Any surplus energy will be stored as fat and flesh which may ultimately become available for human consumption. Finally, the vitamins are essential dietary constituents and supply certain structures or groupings which the body itself is incapable of synthesizing but which are vital parts of enzyme systems necessary for the functioning of the body cells and to maintain health.

The supply of food nutrients in various feedingstuffs is given in the tables on pages 96-121 and guidance as to the requirements of cattle, sheep and pigs for these nutrients, together with suggestions as to the most suitable or economical combinations of feedingstuffs to use, are incorporated in the Bulletin.

DIGESTIBILITY

A feedingstuff may be judged satisfactory when examined chemically and yet prove to have poor feeding value. The reason is that nutritive value is dependent on *digestible* composition and not on crude composition. It is

necessary, therefore, to determine the digestibility of feedingstuffs, by means of digestion trials carried out under controlled conditions in digestion crates or by more modern methods such as using chromic oxide as index material. The assumption made is that all the indigestible constituents of the diet pass out unchanged in the faeces, so that the essential feature of a digestion trial is to determine the total weight of dry dung excreted per 24 hours, and subject it to chemical analysis in the same manner as the food. Thus the total weight of protein consumed per day is determined as well as the average daily excretion of this constituent in the dung. By difference we arrive at the weight of protein that has been digested. Digestibility is expressed in terms of 100 of each constituent consumed, and this figure gives the digestion coefficient per cent. For example if 80 g of protein are consumed in the daily ration and 30 g are voided in the dung every 24 hours, then 50 g have been digested. The percentage digestibility or the digestion coefficient per cent for the protein would be $\frac{100 \times 50}{80} = 62.5$. In the same manner digestion coefficients are determined for the ether extract, nitrogen-free extractives and crude fibre. By multiplying the percentage amount of each food constituent by its appropriate digestion coefficient divided by 100, we arrive at the digestible nutrients. These are commonly expressed per 100 lb of food. The digestible nutrients per cent are the sum of the digestible protein, digestible ether extract, digestible nitrogen-free extractives and digestible crude fibre. They give a much truer estimate of nutritive value than the figures for crude chemical composition.

It should not be assumed, however, that the determination of digestibility is in all cases as simple as this. With concentrated foods like maize or linseed cake, two periods of feeding are necessary. In the first period, the digestibility of a ration composed of known weights of the concentrate and of a roughage is measured. The second period is devoted to the determination of the digestibility of the roughage fed alone. A simple arithmetical treatment of the results enables the digestion coefficients of the concentrate alone to be calculated. This cumbersome method is necessary since if the concentrate is fed alone, the animal would soon become constipated and refuse to eat.

The results of digestion trials with sheep are applicable, without serious error, to cattle but are not applicable to pigs or poultry. Although the pig can digest carbohydrate concentrates almost as efficiently as the ruminant in the case of coarse fodders like hay or straw the position is very different since the pig digests these foods much less efficiently.

Two sets of tables are given on pages 96 and 118, one for ruminants and the other for pigs. These figures must not be taken to apply to poultry since the peculiar digestive system of the bird influences the degree of digestibility of its food. For example, the bird is unable to digest the crude fibre in its food even when it is unligified, since it has no organ comparable with the rumen where the food can stagnate and be fermented by bacteria.

Finally, it is interesting to note that two factors can materially influence the digestibility of certain foods. The first is the stage of maturity of the crop or the degree of lignification and the second is overheating. Grass is much more digestible than hay and overheating in the stack or silo seriously reduces the degree to which the protein can subsequently be broken down to amino-acids. Grinding in the hammer mill can be beneficial and improve the digestibility of certain foods whereas in others it can be actually harmful.

For example, grinding hard small seeds is essential to prevent them passing through undigested into the dung. With straw, however, grinding forces the animal to eat hard indigestible portions which, if fed long, it would normally discard.

KELLNER'S STARCH EQUIVALENTS

DIRECT METHOD OF ASSESSMENT

The yardstick for measuring energy is the gram calorie, the kilogram calorie or the therm. The therm is equivalent to a million small or gram calories. Since feedingstuffs are simply mixtures of energy-rich compounds, it follows that nutritive value can be just as conveniently expressed in calories as in terms of chemical composition.

The gross or total energy of a food can, however, be very misleading as a measure of nutritive value. The reason is that there is an unavoidable and varying loss of energy in the indigestible dung as well as in the urine and breath. Moreover, the body radiates heat and this thermic or heat energy is usually much more than the body needs for warmth and is a pure loss from the standpoint of energy storage in the form of body protein or body fat. It is necessary to deduct these several losses from the gross energy in order to arrive at the amount of energy that can actually be used by the animal for maintenance and productive purposes.

Kellner's pioneer work, which he carried out around the beginning of the century, involved the determination in respiration and balance experiments of the proportion of the gross energy of the food that could be recovered in body gains of flesh and fat. This energy is called the *net energy* of the food. It should be noted, however, that Kellner did not express net energy values in terms of the conventional therm but as starch equivalents. He considered that by substituting for the more technical therm a unit weight of a food constituent, i.e., starch, his system of feeding would be easier to understand and so appeal more to the practical feeder. It should be emphasized, however, that Kellner's starch equivalent system of expressing nutritive values of feedingstuffs is essentially a net energy system. Kellner's unit of comparison refers not so much to 1 lb of starch as to the net energy in 1 lb of starch.

Kellner placed store bullocks in respiration chambers and fed them on the common farm maintenance foods such as meadow hay, roots, oat straw and silage. His aim was to find by trial and error the ration that would just maintain the animals so that they would neither gain nor lose body flesh or body fat. In a second period of feeding a given weight of starch of known digestibility was added to this maintenance ration fed in the first period, and by measuring the storage of carbon and nitrogen he was able to calculate the weight of protein (flesh) and fat laid down by the animal. He found that for every 4 lb of digestible starch added to a maintenance diet the fat and flesh deposited in the body of the bullock had an energy content equivalent to 1 lb of body fat.

In other experiments he replaced the starch with supplements of linseed cake and other feedingstuffs and so determined in a similar way the amount of fat deposited, on the basis of 100 lb supplement. The result he obtained with linseed cake was that per 100 lb added to a maintenance diet 18.5 lb of body fat were deposited. This included any body protein storage computed

on a net energy basis into its iso-dynamic or equivalent weight of fat. It is obvious from the results of the first experiment that had this amount of body fat been produced from a starch supplement, instead of linseed cake, the amount required would have been $(18.5 \times 4) = 74$ lb of digestible starch. This figure therefore represents the starch equivalent of linseed cake.

When the starch equivalent of barley is stated to be 71, it is meant that 100 lb of barley, when fed to sheep and cattle in conjunction with a maintenance diet of hay, roots, silage, etc., has a productive value for fattening equal to that of 71 lb of starch. It must be understood, however, that the full productive value of the barley will only be realised when it is included in the ration of sheep or cattle that is suitably balanced in respect of proteins, minerals and vitamins. Kellner determined the starch equivalents of about 51 samples of 37 representative feedingstuffs by this laborious method.

INDIRECT METHOD OF ESTIMATION

Kellner's object in devising this second method was to enable him to determine starch equivalents more quickly and less laboriously by dispensing with the respiration chamber. The principle involved was to use the digestible nutrients in the food — digestible protein, ether extract, nitrogen-free extractives and crude fibre — and to determine the starch equivalent of each pure nutrient independently. It should then be a matter of simple addition to arrive at the starch equivalent of the feedingstuff. The following example illustrates the method used.

To determine the starch equivalent of the digestible protein in the food, Kellner first prepared a sample of wheat gluten from wheat flour. He chose this vegetable protein because it is representative of the proteins in the mixed diet of ruminants, and it is easily isolated in large quantity and in fairly pure form. The gluten was dried and milled and its digestibility was determined, using bullocks as experimental animals.

The experiment to determine the starch equivalent was in two parts, the bullocks being in the respiration chamber. In part one the bullocks were fed maintenance foods, as described above, the ration being adjusted so that the animals were neither gaining nor losing flesh or fat or, in other words, were in carbon and nitrogen equilibrium. In the second part a known weight of digestible wheat gluten was added to this maintenance diet and its productivity, in terms of body fat and flesh deposited, was determined.

A mean of several such determinations showed that for every lb of digestible protein in the added wheat gluten, the body gain in flesh and fat had an energy equivalent to that in 0.235 lb of fat.

Kellner had previously determined in the same manner that when 1 lb of digestible starch was added to the maintenance diet it led on an average, to the deposition of 0.25 lb of body fat. He therefore stated the starch equivalent of 1 lb of digestible protein to be $\frac{0.235}{0.25} = 0.94$ lb and that the starch equivalent of the digestible protein in any food could be calculated using this factor.

To determine the starch equivalent of the digestible ether extract in feedingstuffs it was necessary to carry out three series of experiments with the bullocks in the respiration chamber. This was necessary because ether extract is not pure fat, and its nutritive value will depend on the amount of useless impurities it contains. In the first series emulsified ground-nut oil

was added to the maintenance diet, and its starch equivalent determined. In the second and third series of experiments oil or ether extract from other sources was used.

The starch equivalents obtained per lb of digestible ether extract were — 2.41 for the oil in oilseeds and oilcakes; 2.12 for the ether extract of cereal grains, leguminous grains and their milling offal; 1.91 for the impure ether extract of coarse fodders, green fodders, silage and roots. Care is therefore necessary in selecting the appropriate factor to calculate the starch equivalent of the digestible oil.

In the same way the starch equivalent of 1 lb of digestible crude fibre, when added to the maintenance diet of the bullocks, was found to be equal in fat-producing value to 1 lb of digestible starch.

The following expression therefore summarises the method of calculating the starch equivalent per 100 lb:

$$SE = \left\{ \begin{array}{l} (\% \text{ dig. crude protein} \times 0.94) + (\% \text{ dig. ether extract} \times 2.41) \\ \quad \quad \quad 2.12 \text{ or } 1.91 \\ + (\% \text{ dig. nitrogen free extractives}) + (\% \text{ dig. crude fibre}) \end{array} \right\}$$

This expression gives the calculated starch equivalent but, as shown below, not the true starch equivalent. To arrive at the latter we have to apply a correction factor.

CORRECTION OF CALCULATED STARCH EQUIVALENTS

Kellner then went on to calculate the starch equivalents of feedingstuffs, using the above factors for the pure nutrients, and to test the applicability of these factors to the common feedingstuffs used for cattle. For this purpose he chose feedingstuffs that were representative of the different groups, and proceeded to make both a direct determination of their S.E. in the respiration chamber and to compare this value with the S.E. calculated from the digestible nutrients and using the factors.

Kellner found that the starch equivalents obtained by the use of the factors were almost invariably too high. He observed, however, that in the case of the concentrates the difference was not great and that the results for these feedingstuffs were very different from those obtained with hays and straws and other roughages. In the case of oat straw, for instance, the true starch equivalent amounted to only 44 per cent of the calculated S.E. Kellner explained this discrepancy as being due to the method of experimentation, since the pure nutrients had been added to the maintenance diet in a powdered or finely emulsified form, requiring the minimum of mastication and digestion. This was in contrast to the manner they naturally occur in feedingstuffs where they are embedded in a mass of indigestible matter. The factors made no allowance for the muscular effort in chewing, regurgitating and moving a mass of indigestible material along the gut, which is considerable with roughages, but of little account when concentrates are fed.

In the case of the oilcakes and meals the agreement between the calculated and determined S.E. were so close that Kellner introduced a correction factor. He called this factor "Wertigkeit" or "evaluating factor" but in this country it is commonly referred to as Value "V". It denotes the percentage that the true S.E. forms of the calculated S.E. Wheat bran, for example, was found to have a "Wertigkeit" of 77.3 per cent. The computed S.E. for wheat bran is therefore multiplied by 0.773 in order to arrive at its production value. The value "V" for feedingstuffs, for which it is appropriate to apply

this correction factor, will be found in column (12) of the Tables of Composition (pp. 96-118).

With the hays and straws and other roughages the very wide difference between the calculated and determined S.E. led Kellner to suggest that this was the result of their high crude fibre content. He therefore proposed with these feedingstuffs to base the correction factor on the crude fibre content and with this end in view he carried out other series of experiments with bullocks in the respiration chamber, to try to correlate the percentage of crude fibre in the diet and the depression of the calculated S.E. He computed from these trials that every 100 g of crude fibre diminished fat production by 14.3 g which is equivalent to (14.3×4) 58 g of starch. To compute the production values of roughages, whether fed long or chaffed, Kellner multiplied the percentage of crude fibre in the food by 0.58 and deducted this sum from the calculated S.E. obtained from the digestible nutrients. For the chaff of cereal grains the diminution in fat production was only one half that found with the corresponding straw, being equivalent to only 29 g of starch, so he substituted the correction factor 0.29.

With green fodders and silage the correction is again based on the percentage of crude fibre, when calculated on the normal moisture content of the green food. If in the green state the crude fibre amounts to 16 per cent or over, the factor to use is 0.58. If the crude fibre is 8 per cent, use 0.38, and if only 4 per cent multiply by 0.29, and deduct this sum from the computed S.E. to get the productive value. For intermediate values a proportional deduction is made.

Subsequent work by Armsby and his colleagues at the Pennsylvania State College, gave distinctly higher values for the net energy in coarse fodders and suggested that Kellner's method of correction led to an undervaluation of their productive value. The late Professor T. B. Wood, from his own observations, agreed with Armsby. This led to his suggestion that Kellner's S.E. for hays and straws should be increased by one-fifth. Woodman gave as his opinion that the increased values for S.E. in hays were justified in that satisfactory results were obtained when used on this basis in the computation of rations for dairy cows and other ruminants, but many expressed doubts about the increased productive value of straws. In the Tables the S.E. of hays, as determined by Kellner's method, have been increased by one-fifth but those of straws are not increased, this practice having been discontinued since the 1948 edition of this Bulletin was published.

NITROGENOUS COMPOUNDS (Crude Protein)

The nitrogenous constituents of feeding stuffs, collectively referred to as crude protein, are divided into two groups — the true proteins, which generally make up the bulk, and the amides.

TRUE PROTEINS

True or pure proteins have very complex molecules built up by the linkage of a series of amino-acids which vary both in identity and number. Each protein has, therefore, a distinctive structure. Moreover, since proteins can be utilized by the animal only after they have been broken down into their constituent amino-acids each protein has a different nutritive or biological value.

BIOLOGICAL VALUE OF PROTEINS

The biological value of a protein is a measure of its efficiency in repairing wear and tear of body tissue in maintenance ; in producing flesh protein in growth, or milk proteins in lactation, or, in the case of sheep, wool protein. Vegetable proteins contain an excess of certain amino-acids but are deficient in others, so they are ill-balanced. Animal proteins have a higher biological value than vegetable proteins because when the flesh protein was laid down the amino-acids present in excess in the food protein were discarded, leaving protein with a better balance. The problem of balance however, is complicated, because the type of amino-acid required in maintenance differs from that required in growth, etc. so that the biological value differs according to the use to which the protein is put.

Again, certain amino-acids can be manufactured in the body from other amino-acids; these are designated as "non-essential". Others, known as essential amino-acids, cannot be synthesized at a sufficiently rapid rate to meet the needs of the body, but must be supplied in the diet.

The biological value of proteins is a matter of considerable significance in the nutrition of the pig, but is of much less importance in ruminants due to the synthetic processes in the rumen.

AMIDES

Amides are all simple compounds and are generally soluble in water. They include all the non-protein nitrogenous compounds such as certain amino-acids, ammonium compounds and true amides, like asparagine. Their nutritional value has intrigued animal nutritionists for a long time and even now has not been determined with certainty.

Since only amino-acids are used to build up flesh and milk proteins or wool, it is necessary, if the amides are to be utilized for these purposes, that there should be some mechanism in the body to convert amides to amino-acids. It is now known that the microflora of the rumen serve this purpose. In the rumen there are numerous micro-organisms which are capable of acting like plants and are able to use amides (even ammonium salts) for the purpose of building up their own tissue protein. When the bacteria die they are passed along the digestive tract and, like food proteins, at least some of their tissue proteins undergo digestion, being broken down into amino-acids, which then become available for utilization by the host animal.

Rumen micro-organisms contribute significantly to the supply of proteins digested in the abomasum and small intestine; it is for this reason that ruminants are less susceptible to critical deficiencies of individual amino-acids in their food protein than the pig or horse. But other interactions between rumen bacteria and food proteins also occur. It has recently been discovered that in certain circumstances a considerable part of the food protein may be converted into ammonia in the rumen and that much of this nitrogen may be wasted. Soluble proteins like casein or grass protein are particularly prone to ammonia formation and the same is true of high-protein silage. Methods of controlling this wastage, and so improving the utilization of the dietary protein by the ruminant, are under investigation in several laboratories.

The accumulation of ammonia in the rumen, and, therefore, the wastage of food protein, is greatly lessened when the diet is rich in starch. Soluble sugars, as in molasses, are much less efficient since they leave the rumen too

quickly. It seems that the feeding of cereal grains with young grass or protein-rich silage, will result in a better utilization of the protein by diminishing this wastage of nitrogen as ammonia.

Before the last war German scientists conceived the idea of using the rumen micro-organisms to convert synthetic amides like urea into protein in order to economize on cake feeding.

Subsequent researches have confirmed the practicability of this idea. But the protein in the diet can only be partially replaced by compounds such as urea and ammonium salts. This may be due to the inability of the bacteria to synthesize some of the essential groupings or structures, or it may be that the rate of synthesis of bacterial protein and its subsequent hydrolysis, is at too slow a rate to support optimum production. American workers have demonstrated that as much as 25 per cent of the nitrogen requirement of growing dairy cattle and milking cows, can be furnished by urea without affecting growth or milk yield. Again at least 25 per cent of the total protein requirement of fattening bullocks can be supplied in this way, which implies that at this level of feeding, non-protein nitrogen has the same nutritive value as digestible food protein. From several investigations it seems that the type of amino-acid manufactured by rumen bacteria is at least as good as if not better than, that obtained from the digestion of vegetable food protein.

Certain precautions are necessary when urea or ammonia salts are used as a partial substitute for dietary protein. It is most important that they are thoroughly mixed with the other ingredients of the diet since failure to do this will give rise to toxic symptoms or even death. The level of tolerance is not known with any degree of certainty. Urea makes no contribution to the palatability of the diet and ammonium salts may distinctly depress food consumption; a serious disadvantage with high producers.

EVALUATION OF PROTEINS

The percentage of crude or total protein in a feedingstuff is found by determining the percentage of total nitrogen, using the Kjeldahl method, and multiplying the result by the factor 6.25. The latter is based on the fact that proteins on an average contain 16 per cent of nitrogen, and $\frac{100}{16} = 6.25$.

The percentage of true protein is determined from the nitrogen content of compounds precipitated by copper salts under specified conditions. The percentage of amides is then arrived at by simple subtraction:

Crude protein percentage—True protein percentage=Amides percentage.

It is fairly easy to determine the percentage of true protein in the food, but for technical reasons it is impossible to do this satisfactorily on the faeces of animals. Consequently analysts cannot make a direct determination of the digestibility of the true protein. A value for digestible true protein can be arrived at, however, by deducting from the percentage of digestible crude protein, determined in digestibility trials, the figure for the percentage amides arrived at from the analysis of the food:

$$\begin{aligned}\% \text{ dig. true protein} &= \% \text{ dig. crude protein} - \% \text{ amides} \\ &= \% \text{ dig. crude protein} - (\% \text{ crude protein} - \% \text{ true protein}) \\ &= \% \text{ dig. crude protein} - \% \text{ crude protein} + \% \text{ true protein}\end{aligned}$$

This method of assessment assumes that the amides are completely assimilable. In the Tables on pp. 96–118 figures are given in column (7) for the actual true protein content of the feedingstuffs used for ruminants, from which, if

necessary, the value of the percentage digestible true protein can be computed from the data in columns (2), (7) and (8) by the above formula.

PROTEIN EQUIVALENT

In order to give recognition to the fact that amides have some nutritive value, British scientists in 1925 decided, on the limited evidence then available, to assign to amides one-half the value of true protein, and introduced a new term, "protein equivalent". The protein equivalent of a food was defined as the sum of the percentage digestible true protein and half the percentage of the amides. The proportion of amides in ripe fodders and hays, and in concentrates from ripe grains and seeds is usually quite small, but considerable amounts may be present in roots, tubers, malt culms and certain green fodders like kale and pasture grass. With the latter the protein equivalent value should provide a better assessment of nutritive value than is given by the figure for digestible crude protein.

Calculation of protein equivalents from the data given in the tables involves two steps as follows:

- (1) Calculate percentage of digestible true protein as above.
- (2) Protein equivalent = $\%$ dig. true protein + $\frac{1}{2}\%$ amides
 $= \%$ dig. true protein + $\frac{1}{2} (\%$ dig. crude protein — $\%$ dig. true protein)
 $= \frac{1}{2} (\%$ dig. crude protein + $\%$ dig. true protein).

It will be seen, therefore, that the protein equivalent is the arithmetic mean of the percentages of digestible crude protein and digestible true protein. Its calculation is carried out as in the following example:

Swedes

Digestible crude protein	.	= 1.1 per cent (column 8)
Digestible true protein	.	= 0.3 per cent
Protein equivalent	= $\frac{1}{2} (1.1 + 0.3)$	= 0.7 per cent

When computing the digestible protein content of a ration containing swedes, therefore, the contribution of the swedes, per 100 lb, should be shown as 0.7 lb and not 1.1 lb. A similar precaution applies to all other foods rich in amides, such as turnips, mangolds, potatoes, kale, etc.

In the Tables, calculations have been made of the protein equivalents of all foods (except silage) used for ruminant animals where digestibility data are available.

It will be obvious from the above discussion that the figures for "protein equivalent" are not above criticism as a measure of protein requirement or as a statement of nutrient value. It should also be pointed out that the non-ruminant cannot utilize amides or ammonium salts, to manufacture amino-acids, since bacterial action in these animals takes place only in the large intestine. Such compounds have been absorbed before the food reaches this part of the digestive tract.

However the evaluation of amides probably errs on the safe side. Many authorities are of the opinion that, provided the amides are present in moderate amount they have a value equal to and possibly higher than digestible plant proteins for ruminants.

Finally it may be noted that the position of silages is anomalous. During the fermentation which ensues when a green fodder is ensiled there is a normal breakdown of a considerable proportion of proteins into the constituent amino-acids. With a lactic type of fermentation this breakdown stops at this point, so that in effect the animal is presented with its proteins largely in a predigested form. With underheated butyric types of silage further

breakdown of amino-acids to volatile nitrogenous bases occurs to a variable extent.

Unfortunately the analytical technique for determining true protein cannot clearly differentiate between the various amino-acids, some being included and some omitted. Consequently a true protein determination with silage can give a misleading impression. The amide fraction may well include a proportion of amino-acids that, in effect, have a true protein worth to the animal. Until better techniques are available it seems advisable to record the protein value of silage in terms of "Digestible Crude Protein" and to avoid the use of the term protein equivalent. Consequently no figures are given for the protein equivalents of silages.

VITAMINS IN STOCKFEEDING

Up to about 1912 it was generally believed that provided the diet supplied sufficient digestible protein, fats, carbohydrates and minerals it contained all ingredients essential to support maximum growth. But evidence began to accumulate to throw doubt on this belief. It became clear that in natural foods there exist minute amounts of organic compounds which are vital to the well-being and proper nutrition of the animal organism; in the absence of these, deficiency symptoms appeared and eventually death occurred. These substances were first referred to as "accessory food factors", but later as "vitamins". The existence of over 20 vitamins has now been established beyond doubt, and at least 14 of these have been actually synthesized in the laboratory, a remarkable feat in view of the complexity of some of their structures. In this Bulletin space permits reference only to certain aspects regarding the vitamins that are of special interest to the stockfeeder.

VITAMIN A

This vitamin, as such, is not present in vegetable foods, but fortunately its precursor carotene is quite widely distributed. Carotene is one of the yellow pigments present in all green fodders, as well as in carrots, and is converted into vitamin A when absorbed through the wall of the intestine. However, not all the carotene is converted in this way. Some is absorbed unchanged to be deposited in the body fat or enters the milk to give the butterfat or cream its rich yellow colour. The vitamin A not immediately required is deposited mainly in the liver. When the animal has been grazing throughout the summer its stores of carotene and vitamin A will be large, but these will be gradually released during the winter months to keep up the colour of the cream, etc. Towards the end of winter, however, unless the diet has contained kale or grass silage, or similar foods, these reserves will be depleted and the cream will lose its yellow colour.

The young of mammals when born have a store of the vitamin in their liver, provided the diet of the dam contained sufficient carotene. This is further augmented by the colostrum which can be a very rich source of vitamin A and carotene. A winter diet of straw, roots and concentrates has, however, very little vitamin A potency.

It is interesting to note that the rich colour of the egg yolk is not due to carotene, but to the other yellow pigment of green food, namely xanthophyll. Again the colour of yellow maize is due to two pigments called zeaxanthin.

which is not a vitamin precursor, and cryptoxanthin with about half the potency of carotene in grass as a source of vitamin A.

Symptoms of vitamin A deficiency vary considerably in the different species and are summarized below.

CALVES AND CATTLE

The first symptom is night blindness and this may occur even though the cattle appear quite thrifty and are gaining in weight. Undue prolongation of this condition leads to permanent day blindness, accompanied by atrophy of the optic nerves. As little as 1.5 mg carotene per 100 lb live weight will protect against night blindness, but allows little storage in the liver. It is therefore recommended that to maintain health the diet should supply 6 mg carotene per 100 lb live weight. A 300 lb calf will secure this amount of carotene from $\frac{1}{4}$ lb of dried grass supplying 20 mg carotene per 100 g dry matter.

The requirement of the dairy cow for lactation and normal calving will be met provided the diet in the initial stages supplies 60 mg carotene, but this should be stepped up to 90 mg about 3 months before calving is due. Failure to supply the necessary amount will lead to weak or dead calves. The farmer should ensure sufficient green food in the diet in winter to enrich the milk in colour and vitamin A, and in addition, to provide for the needs of the cow and its calf. Carotene also safeguards the flavour of the milk in winter.

PIGS

Pigs with good liver reserves of the vitamin at weaning may not show symptoms of vitamin A deficiency until they attain about 250 lb live weight, though their diet may contain but little carotene or vitamin A. The first symptom is diminished appetite, with loss in weight, but, unless some green food or a little cod liver oil is now provided, injury to the central nervous system accompanied by partial or total paralysis may occur. The requirement per 100 lb live weight is similar to that of the calf, amounting to about $\frac{1}{2}$ mg of carotene or less, though again a safer standard to adopt is 4 mg per day, or about the quantity supplied in an oz of dried grass meal. Possibly the easiest way to ensure sufficient vitamin A is to include about three per cent of artificially dried grass or lucerne meal in the meal mixture. For further information on the feeding of vitamin A to pigs the reader should consult the pig-feeding section (see page 85.)

POULTRY

With young chicks the earliest sign of vitamin A deficiency is difficulty in standing, and even when squatting the birds are unsteady and liable to fall down. Appetite and growth may remain normal in spite of progressive weakness. Death follows in about 6 days with evidence of kidney damage unless supply of vitamin A is given. The leg weakness and uncertain gait of depleted chicks is a good indication and is quite distinct from rickets.

With older fowls, the males become bow-legged and later suffer brief loss of consciousness. The cockerels make a gurgling sound, flap their wings a little and then fall as if dead. The bird recovers in as little as 30 seconds and within 5 minutes is eating again. The older females develop marked leg

weakness and are often found sitting or leaning against the side of the cage and take no interest in their food. Xerophthalmia does not occur.

Considerable advance has been made recently in stabilizing the vitamin A in feedingstuffs so as to prevent deterioration and loss on storage, and usually enough stabilised vitamin A is added to make the animal independent of carotene.

VITAMIN B COMPLEX

The factors making up the vitamin B complex are:

- (1) Vitamin B₁ known as thiamine and protective against beri-beri in man and polyneuritis in fowls.
- (2) Nicotinic acid, protective against pellagra in man.
- (3) Riboflavin, an important growth factor, and of special importance to the young chick and the laying hen.
- (4) The rat-dermatitis protective factor known chemically as pyridoxine. It has been found to be a dietary essential for rats, pigs, chicks and dogs, and is effective in curing certain skin lesions in man. It is widely distributed in feedingstuffs.
- (5) The chick-dermatitis protective factor, known chemically as pantothenic acid.
- (6) Vitamin B₁₂, preventative of pernicious anæmia in man, a growth factor and influences hatchability of eggs.

The bacteria that flourish in the rumen are capable of synthesizing all the B vitamins so that the ruminant is independent of a supply of these vitamins in its food. Under conditions of cobalt deficiency, however, sheep and, to a lesser degree, cattle are unable to synthesize the necessary amount of vitamin B₁₂, and a disease called *pinning* then becomes manifest.

The factors of the B complex are needed for the maintenance and normal functioning of the nervous system. The normal rations of pigs and poultry contain liberal allowances of cereal grains and wheatfeed, and these feedingstuffs are good sources of vitamin B₁ of which the best source of all is unextracted dried yeast. It is rarely necessary to add synthetic thiamine to compound feeding stuffs.

NICOTINIC ACID

Nicotinic acid, also known as niacin, is required by dogs, monkeys and pigs. The rat and the calf and other mammals can synthesize the vitamin from the amino-acid tryptophan. It is unlikely to be deficient in the diet of farm animals, even wheat straw as litter protects the pig from deficiency.

RIBOFLAVIN

Riboflavin is the greenish-yellow pigment frequently noted in whey and in the white of eggs from hens on grass. Summer milk is also a well-recognized source of riboflavin. The vitamin is now widely produced, at a reasonable price, by chemical synthesis and by fermentation processes, for inclusion in compound mixtures. Liver meal and dried yeast are outstanding sources of the vitamin but cereals are a poor source. Appreciable quantities are also found in dried green foods and animal protein materials as well as in oilcakes.

Riboflavin not only influences the number of eggs laid but also their ability to hatch out vigorous chicks. In the absence of riboflavin, characteristic defects develop in the embryos after a period of incubation. Young chicks on diets deficient in riboflavin develop "curled toe" paralysis, so called because of the way the toes curl in and under.

PYRIDOXINE (Vitamin B₆)

Pyridoxine was obtained pure in 1938 and appears to play some part in amino-acid metabolism. The vitamin is so widely distributed in feedingstuffs that the addition of the synthetic vitamin to compounds is unnecessary.

PANTOTHENIC ACID

Dried grass is a rich source of this vitamin and it is unlikely to be deficient in normal diets.

CYANOCOBALAMIN (Vitamin B₁₂)

As its name implies vitamin B₁₂ contains cobalt as part of its molecule. It is intimately associated with *pinning* in sheep and cattle. (Human beings with pernicious anæmia are unable to absorb sufficient B₁₂ unless it is given with another substance called "intrinsic factor" elaborated by the gastric mucosa). Vitamin B₁₂ influences the metabolism of carbohydrate, fat, protein and nucleic acid, and stimulates bacterial synthesis of methionine and reduces the need for choline.

When pigs and chicks have subsisted for some time on all-vegetable diets there is a tendency for their tissues to be depleted of vitamin B₁₂. Chicks hatched from the eggs of hens that have suffered B₁₂ deficiency require a B₁₂ supplement in order to attain the optimum or quickest rate of growth. Similarly the eggs will have poor hatchability.

It seems that little is to be gained by supplementing the diet of weaners with B₁₂ since they seem to carry sufficient reserves in their liver, from the suckling period, to carry them over until bacterial synthesis becomes established. The micro-organisms are ultimately responsible for vitamin B₁₂ found in animal tissues.

All *animal* feedingstuffs serve as a source of vitamin B₁₂.

VITAMIN C

In its synthetic crystalline form, vitamin C is known as ascorbic acid. It protects man, monkeys and guinea pigs from scurvy. This vitamin is of little interest to the stockfeeder since farm animals remain perfectly healthy on diets deficient in vitamin C. The explanation is that farm animals are able to synthesize the vitamin which makes them independent of a supply in the food. It is noteworthy that the level of vitamin C in cows' milk cannot be improved by feeding a rich source of the vitamin, since the bacteria in the rumen will destroy ascorbic acid. The level of vitamin C in milk therefore tends to remain constant throughout the year and is distinctly lower than in human milk. Moreover a bottle of milk left in sunlight over a short period will have most of its vitamin C destroyed. Vitamin C is a preventative of "oxidative flavour" in milk.

VITAMIN D₂ AND VITAMIN D₃

Vitamin D is associated with vitamin A in the liver oils. It plays an essential role in the absorption of lime and phosphate from the intestine and, therefore, in the calcification of the teeth and skeleton, as well as in the formation of a strong egg shell. When the supply of bone-forming minerals is subnormal vitamin D ensures that the animal makes the best use of what is available.

The vitamin is not present as such in the vegetable kingdom, but is the result of the action of ultra-violet light on sterols such as ergosterol or dehydro-cholesterol. When the skin of man or animal is exposed to sun-

light or to artificial irradiation with ultra-violet light, the 7 dehydrocholesterol is converted into vitamin D₃ (cholecalciferol) which can be utilized by the body, or stored in the liver oils, or passed into the butter fat. Summer milk is, therefore, a much better source of vitamin D than winter milk. When ergosterol is irradiated by sunlight over a long period a highly potent but different vitamin D is produced, known as ergocalciferol or vitamin D₂. Thus well-bleached hay will contain some vitamin D₂ in spite of the fact that the green grass contained none. During haymaking the ergosterol in the grass becomes irradiated. It is unwise, however, to rely on hay as a source of the vitamin, since the amount is so variable. That the two vitamin D's are different is demonstrated by the fact that ergocalciferol is almost useless for poultry though highly potent for pigs, sheep and cattle.

In the absence of vitamin D, or when the diet is ill-balanced with regard to the supply of lime and phosphate, a disease known as rickets occurs. Abnormal bone development is shown, the bones being soft and fragile, break easily, and eventually the animal becomes lame or unable to move. The spinal column may be curved and the hock joint swollen.

The reserves of vitamin D in the egg yolk will protect the chick for about three weeks, and if reared under the intensive system the chick must then have vitamin D₃ in its diet unless it gets sufficient from exposure to sunlight.

The baby pig's requirement of vitamin D is small and, in a well-lit piggery, is supplied by the action of sunlight. From the standpoint of growth and bone formation of the baby pig reared indoors, it is a wise safeguard to include a small amount of vitamin D in the diet in winter. Ram lambs have been reported as suffering from rickets both in this country and in Australia and "bent leg" is probably a manifestation of this disease.

VITAMIN E

This is the anti-sterility vitamin with the chemical name of α -tocopherol. It is very widely distributed in feeding stuffs and there is no evidence that vitamin E either improves fertility in farm animals or influences the number of young born. Vitamin E is present in green fodders and in cereal grains, particularly in the oil in the germ. Wheat-germ oil is a rich source. Considerable storage of the vitamin occurs, but the possibility that the rumen bacteria have the power of synthesizing the reproductive vitamin, as is the case with the B vitamins, has neither been proved or disproved. The absence of the vitamin from the diet of goats led to no reproductive failure or disturbance over a long period.

Of far greater significance to the stock feeder is the fact that the prolonged absence of vitamin E from the diet leads to muscular dystrophy, a condition due to the degeneration and atrophy of the muscles. Similarly lack of the vitamin in the ration of growing chicks results in "crazy chick disease" (encephalomalacia), an acute nervous disorder which usually manifests itself at 4-5 weeks of age, when the reserves from the egg have been depleted.

Lambs kept on a diet deficient in vitamin E develop a form of muscular dystrophy called "stiff lamb disease". Calves born in the late spring may have very low reserves of vitamin E, particularly if the winter diet has contained little green food so that the reserves of the cow are also low. The disease known as "white-muscle disease" is usually fatal, but can be prevented by giving α -tocopherol. The feeding of as little as $\frac{1}{2}$ oz of cod liver oil may lead to a severe exacerbation of the disease but antioxidants prevent it.

MINERAL REQUIREMENTS OF LIVESTOCK

When an animal's carcass is completely burnt the residue consists of inorganic substances termed "mineral matter" or "ash". The quantity of ash in the body normally lies between 3 and 5 per cent of the total weight. A large number of elements probably over 50, can be detected in the ash in greater or lesser amounts. Calcium is present in largest quantity, followed by phosphorus, while sodium, potassium, chlorine, sulphur and magnesium comprise the greater part of the remainder. The presence of these elements as major components of the ash is not fortuitous, since they have important parts to play in the structure of the body and in the proper functioning of many of its vital processes. Other elements are found in smaller but significant amounts in the ash and many of these also have a vital part to perform. Amongst these may be listed copper, iron, iodine, manganese, cobalt, zinc and fluorine. There are others whose presence may be essential but for which a definite role has yet to be assigned: and yet others which have no part to play, but whose presence may be a matter of chance in that they happen to have been in the food and have been absorbed and stored in various organs of the body. It is not easy to distinguish absolutely between essential and non-essential elements, for as our knowledge of the biochemistry of vital functions advances it is possible that elements, at present regarded as non-essential, may be found to be necessary.

Deficiencies of both major and minor elements may adversely affect animal production and performance, and on the other hand, the presence of some elements in more than normal traces in the food may give rise to disease or toxic symptoms. The presence of one element may have a profound effect on the activities of another; one may aid the other in some instances, or considerably modify its action in others. In recent years these inter-relationships of various elements have been intensively studied, but our present knowledge is still very incomplete.

Amongst the functions of mineral elements in the body are the following:

- (1) Some help to confer shape, rigidity and strength to the skeletal structures, including the teeth.
- (2) Others are important components of the soft tissues and their various secretions.
- (3) They may act as vital links in enzyme-chain systems.
- (4) They are intimately concerned with the utilization of digested food products.
- (5) Minerals are an essential aid to maintaining a steady composition of blood, lymph and cellular fluids and the correct degree of acidity and alkalinity of these fluids.
- (6) Some play a most important role in the water relationships of the body.
- (7) They are essential in maintaining "tone" in muscular and nervous tissues.
- (8) Finally they have a productive function in the composition of the growing and fattening tissues, and of eggs, milk and wool.

It must be remembered that minerals enter closely into the composition and make-up of foods of both plant and animal origin given to livestock. The amounts in which they are present are very variable, and it may be and often is necessary to provide additional minerals in order that the animal may develop and remain healthy, and sustain the high levels of production demanded of it by present-day economic circumstances. Moreover, the provision of mineral supplements may be necessary to prevent the appearance of disease symptoms, or to combat circumstances that otherwise would lead to the death of the animal or its offspring.

The animal body varies considerably in its ability and capacity to utilize and to store minerals. Unfortunately our present methods of assessing the true mineral requirements of animals are very inexact and the extent to which minerals present in the food are "available" to the animal is very imperfectly understood. Very arbitrarily we assume a 50 per cent availability of food minerals, so that we endeavour to supply through the food intake at least double the quantity that we know is leaving the body in the form of milk or eggs produced.

There are certain generalisations that can be made when considering the needs of livestock for minerals. Vegetable foods contain ample amounts of sodium and potassium. Cereal foods are usually very deficient in calcium and chlorine, but contain fair levels of phosphorus. The vegetative parts of green foods are usually richer in calcium than phosphorus, and leguminous fodders such as clovers and lucerne, may indeed be very good sources of calcium. On the other hand pastures on poor acid soils may not contain sufficient mineral elements, major and minor, to sustain full productivity and to keep grazing animals healthy. Animal protein foods, containing a proportion of bone in their make-up, are usually rich sources of calcium and phosphorus. The tables of mineral composition in the Appendix (pages 122-124) give some idea of the distribution of the major elements in the commoner feedingstuffs although it must be appreciated that there may be a wide variability in the amounts present.

CALCIUM AND PHOSPHORUS

These two elements are so closely associated in many of their functions that it is convenient to consider them together, for they comprise the major part of the total ash content of the body. More than 98 per cent of the calcium is located in the bones and the teeth, and at least 80 per cent of the total phosphorus is also found in these structures.

The bones confer rigidity and shape to the body as well as protecting and enclosing the brain and spinal cord. Too often the bones are regarded as inert structural material, comparable with the steel girders of a modern building, instead of as living material, acting as a reservoir or storehouse for calcium and phosphorus. When milk production levels are at their highest the bones may give up a high proportion of their calcium and phosphorus in order to keep the mineral composition of the milk up to normal levels, if the amounts of these elements available from the foods are insufficient to sustain the total output from the animal. Bones are thus constantly in a state of being built up or broken down, and in order to supply the body's requirements for production their reserves of calcium and phosphorus may at times be called upon heavily, to be replenished later when production demands have declined, provided sufficient is available in the diet.

Deficiencies of calcium and phosphorus in the rations of growing animals lead to poor bone development. The absorption, assimilation and deposition of these elements is also in some way controlled by the presence of adequate amounts of vitamin D in the diet. Calcium is needed by the laying fowl to provide for the formation of the shells of eggs and in the absence of sufficient calcium in the ration the bird tends to produce shell-less eggs and later may cease to produce eggs at all. At low and insufficient levels of phosphorus intake the young animal develops poorly and may show a depraved appetite and symptoms of wasting, as in the classical condition of *aphosphorosis* first

own in South Africa and later in many other parts of the world. An important manifestation of low and insufficient levels of phosphorus intake in lactating dairy cows is temporary infertility. In many instances infertility problems have been successfully resolved by an adequate supplementation of the diet with phosphorus, in the form of inorganic phosphates such as ground bone flour or dicalcium phosphate.

It is not easy to lay down precise requirements of farm animals for calcium and phosphorus. It has been commonly accepted that the maintenance needs of adult cattle could be met by the provision of 1.5 oz calcium (expressed as CaO) and 0.8 oz phosphorus (expressed as P_2O_5) though the evidence was slender and American work has suggested that half this allowance of calcium would be sufficient. Other workers have suggested that this level of phosphorus was inadequate for proper reproductive efficiency in dairy cows and that double this amount, namely 1.6 oz of phosphorus (expressed as P_2O_5) was necessary to prevent infertility. Yet others have laid stress on maintaining an appropriate calcium : phosphorus ratio in the diet, and an adequate intake of vitamin D. It is difficult to lay down precise standards, and the position is complicated by our very imperfect knowledge of the availability of the minerals from different sources.

The mineral composition of milk is tolerably constant and each gallon of average milk contains about 0.25 oz of calcium (expressed as CaO) and 0.33 oz phosphorus (expressed as P_2O_5). If we assume conventionally that the availability of these elements in the food is 50 per cent the ration for each gal. of milk should contain 0.5 oz CaO and 0.66 oz P_2O_5 . The feeding of 4 lb balanced concentrates containing these quantities should involve a content of not less than 0.8 per cent calcium (expressed as CaO) and of not less than 0.8 per cent phosphorus (expressed as P_2O_5). The balanced foods for milk production usually comprise cereals and vegetable-protein foods. Without mineral supplementation they will be notoriously low in calcium and chlorine and contain only moderate levels of phosphorus. The mineral supplement will therefore need to be fairly rich in calcium and chlorine and contain some additional phosphorus.

At the height of her lactation, and despite the inclusion of adequate minerals in her production ration, the cow is usually in negative calcium and phosphorus balance and draws upon the reserves in her bones to maintain the mineral content of the milk. As her yield of milk becomes less the output and intake of minerals come more into equilibrium so that towards the end of lactation she begins to replenish the reserves in the bones, provided the mineral intake in the ration is adequate. During the dry period and the associated feeding of a steaming-up ration, the mineral reserves should be brought up to normal in preparation for the next lactation.

With pigs and poultry which normally receive a proportion of animal protein foods (containing bone) in their diets, the provision of a phosphate supplement may be unnecessary and the major mineral supplementation can be 1 to 2 per cent of ground chalk or limestone flour, and 0.5 per cent of salt.

CHLORINE

Chlorine in the form of common salt is a most important element for helping to maintain the correct water balance in the fluids and tissues of the animal body, and for assisting in gastric digestion. With the usual unsupplemented diets of livestock the intake of salt may fall below optimum levels,

but the body is very zealous in its conservation of salt, and low intakes compensated for by low outputs of salt in the urine. Under hot climatic conditions excessive loss of salt may occur through sweating and a craving for salt may ensue. The presence of salt at adequate levels in the diet is an important factor in the palatability of food, and a salt-low diet is usually unappetising. Excess salt, on the other hand, considerably increases the demand for water in order to eliminate the surplus from the body and may render the food unpalatable. It is unwise to exceed 1 per cent salt in the diet of any animal, since the optimum level of intake for most animals lies between 0.5 and 1 per cent of the dry food intake. If more appears to be needed provision should be made for voluntary consumption by supplying salt licks or lumps of rock salt. An enforced consumption of very salty food by simple-stomached animals may give rise to vomiting, a reflex action that helps to guard the animal against salt poisoning. Some foods are naturally and perhaps unexpectedly high in salt content, e.g., sugar beet tops which may contain more than 5 per cent salt in their dry substance, and the provision of adequate drinking water for all classes of livestock is an important tenet of good husbandry.

MAGNESIUM

Generally speaking it is unnecessary to provide farm animals with supplementary magnesium since this element is normally present in adequate quantities in foods. However, in certain circumstances cows turned out to grass in spring, in-lamb ewes at the end of the winter, and calves fed exclusively on whole milk, develop a condition of staggers or tetany characterised by a drop, usually a sudden one, in the magnesium content of the blood. Unless a soluble magnesium salt is rapidly injected into them they may die within a short time. This condition is often loosely and incorrectly termed magnesium deficiency.

Although pastures may have an adequate magnesium content in the spring, nevertheless, an additional intake of a magnesium compound such as calcined magnesite (continuously administered over the susceptible period of spring grazing and sometimes during the autumn flush of grass also) fed at a level of about 2 oz per head of cattle per day, seems to be a very useful prophylactic against the condition. Reports on the value of magnesium fertilisers applied to the herbage are somewhat conflicting, and it seems good practice to incorporate a magnesium supplement in the food under conditions where there is a marked susceptibility to staggers. It has been suggested that feeding cubes containing calcined magnesite is the easiest way of administering magnesium in the spring.

IRON

The iron content of the animal body is very small, probably of the order of 0.004 per cent. Nevertheless iron is a most important constituent of haemoglobin, the pigment in the red blood cells, on which depends the ability of the blood to transport oxygen to every cell in the body. With a deficiency of iron a state of anæmia gradually develops. Iron is stored to a very limited extent in the liver, spleen and bone marrow. Anaemia is not normally a serious problem in livestock, which usually have access to soil, a rich source of iron, but in certain circumstances this can occur. Young pigs, for example are

born with relatively small iron reserves in their bodies, and they grow so rapidly that they double their weight and hence their blood volume in a week or ten days. Milk is a very poor source of iron (and incidentally of copper and manganese) and since this is the sole food of the very young it is not uncommon for pigs to develop an anaemia in the first fortnight of their lives, especially under indoor conditions of husbandry. It is not possible to increase the iron content of the milk of the sow by providing her with extra dietary iron. Young pigs reared out of doors on pasture seem to acquire all the iron they need, but when reared indoors they may show a tendency towards anaemia. The provision under such conditions of fresh sods of pasture or a box containing soil can be a help, but nowadays it is more usual to dose the pigs with iron preparations of a non-astringent nature, or to inject proprietary compounds containing iron and other stimulants to aid blood formation, and to combat any tendency towards anaemia. Iron is an element which is not well absorbed from the diet, but, apart from special circumstances, the sources available to the animal in its food and from its environment are generally adequate to provide for its needs without any specific supplementation.

MINOR OR TRACE ELEMENTS

Over the last thirty years there has been a great increase in our knowledge of the role of trace elements in animal nutrition. These may be defined, somewhat loosely, as elements present normally in foods in very small quantities, of the order of a few parts per million. Nevertheless, their presence is a most important factor in the adequate nutrition of farm animals. In many parts of the world where they have been absent from or present in insufficient amounts in the soil and pastures, there have been serious economic losses in stock through failure to make adequate growth or to survive. It is unnecessary to review in full all these conditions, but it is sufficient to state that as a result of intensive studies all over the world clear-cut evidence has been established of the need of animals for such elements as cobalt, copper, manganese and iodine. Under conditions of intensive husbandry where high levels of production are required, some of these trace elements are indispensable to success. Every year brings new additions to the general pool of knowledge of the needs of animals for these elements. Further, adverse effects on the productivity and health of animals have been often demonstrated when certain elements are present in or on the food in amounts greater than the normal traces, and such effects may include persistent scouring, malformations of bones and teeth and toxicity leading to extreme unthriftiness and even death.

Some elements necessary for health and normal development at levels of a few parts per million, such as copper, may have very adverse effects leading to chronic or acute poisoning when more liberally administered. Sometimes the beneficial influence of a particular element added to the diet of livestock may produce adverse effects when its administration is unduly prolonged.

The amount of trace elements varies widely not only in different sorts of food, but also in food of one kind. It is unlikely that any animal in this country receiving as its diet a mixture of foods grown in different parts of the world, will suffer from any deficiency of trace elements. Some animals, such as hill sheep that rarely receive any concentrated food, may derive their total nourishment from the grazing and hay made from the grass growing on

a particular soil type, and here the possibility of some trace element deficiency such as cobalt is a real one. Such deficient areas are becoming known through failure of the sheep to make adequate growth or through specific manifestations of ill health associated with the deficiency. The remedy is an obvious one, and measures to counteract the deficiency include pasturage dressings with appropriately supplemented fertilizers and the provision of minerals or licks containing the deficient element. In some areas the disease of lambs known as "swayback" can be very largely controlled by administration of additional copper to the pregnant ewe, although the pastures may not actually be deficient in copper.

But with the majority of animals receiving a mixed diet the probability of trace-element deficiencies is a fairly remote one. It is now customary for manufacturers of mineral supplements to include in their formulations not only the major mineral elements, calcium, phosphorus, sodium, chlorine and often magnesium, but also small quantities of iron, copper, cobalt, iodine, manganese, sulphur and perhaps zinc. These minor additions do not materially add to the cost of the mixtures, and it is argued that they act as a kind of insurance against the possibility that the diet may not naturally contain sufficient of these trace elements to meet the full needs of the animal. Our knowledge of deficient areas in this country is continually increasing, (i.e. areas where the natural level of a specific element or elements in the food grown upon them is too low to support the production demanded by present-day economic circumstances). But this knowledge is not yet sufficiently exact to indicate when and where a particular deficiency of one or more trace elements may be the limiting factor in health and production. The use of general purpose mineral mixtures can be of benefit, and if unnecessary there is little risk of toxicity arising from the low levels at which these trace elements are normally included in the mixtures.

On the other hand there is a school of thought that is opposed to what may be termed indiscriminate medication of foods. Most animals kept intensively receive a considerable proportion of their foods in concentrated form and the diet, comprising cereals, vegetable or animal high-protein concentrates with appropriate major mineral and vitamin supplements, is drawn from so many different sources that it is highly unlikely to be deficient in minor elements. The farmer who purchases a proprietary mineral mixture today will almost certainly be getting one fortified with a number of minor elements; if, however, he decides to prepare his own from simple "straight" ingredients, for mixing in with a balanced concentrate food, also home-prepared, there is little need for him to concern himself with ensuring that all the "bits and pieces" are included, for these will be present naturally in the foods he is using.

SUGGESTED MINERAL MIXTURES

A. Cattle and Sheep

Add to the balanced concentrated food 3 lb of the following mineral mixtures per cwt of food (or about 2 stones in half a ton of food).

	Parts by weight
Limestone flour or ground chalk	1
Steamed bone flour	1
Common salt	1

Where commercial dicalcium phosphate is used as the source of phosphorus the mixture may consist of:

	Parts by weight
Limestone flour or ground chalk	6
Dicalcium phosphate	4
Common salt	5

3. Pigs

1. Where the diet contains 10 per cent fish meal or meat and bone meal it should not be necessary to add any further minerals other than 7 lb salt per ton.
2. Where the diet contains $7\frac{1}{2}$ per cent fish meal or 5 per cent meat and bone meal the mineral addition should be about 1 per cent limestone flour or ground chalk ($1\frac{1}{2}$ stones per ton) and 0.5 per cent salt (10 lb per ton).
3. With 5 per cent or less of fish meal or its equivalent in other animal protein foods the mineral supplement may consist of 2 per cent (3 stones per ton) of the mixture:

	Parts by weight
Limestone flour or ground chalk	3
Common salt	1

4. If the diet contains vegetable protein concentrates only it is best to add one part of sterilized bone flour to the above mixture and to feed again at the 2 per cent level (3 stones per ton).
5. Where the dry feeding system is practised it is advisable to add $\frac{1}{2}$ lb zinc carbonate per ton of the food as an aid to preventing the peculiar skin dermatitis known as parakeratosis.

MINERALS AT PASTURE

It is relatively easy to ensure that stall-fed animals receive an adequate intake of minerals by incorporating the recommended quantity in the concentrates they receive or by mixing in the appropriate allowances with a small quantity of damp food such as soaked beet pulp or wet brewers' grains. The problem becomes more complicated with animals at pasture since they may not normally receive any supplementary feeding at all over the summer months. Generally speaking, good grazing on fields that are regularly dressed with mixed fertilizers should contain sufficient minerals for maintenance and productive needs, but there may be circumstances in which it is essential to ensure an adequate intake of general or specific minerals. With some elements such as copper or cobalt the pastures can be sprayed (where practicable) with a few pounds per acre of an appropriate salt of the element in solution, and such a method usually ensures adequate protection against a deficiency condition for the duration of at least one grazing season. Alternative methods include the provision of appropriate mineral supplements in boxes suitably protected against adverse weather, generally placed in the vicinity of the animals' watering place; or the manufacture of the supplements into suitable "bricks" or "licks", which are then scattered on the pasture. These methods however rely on the principle of voluntary consumption and there is no guarantee that each animal will actually obtain its fair share. Most animals are attracted by salt and it is usual to include salt amongst the ingredients so that it acts as a vehicle for the particular element that is necessary to protect them against a specific deficiency. This principle of

voluntary consumption seems to be most effective where the deficiency largely of a minor element, since the requirements of such elements in animals are usually very small, and even the occasional taking of the mineral may be fully effective to guard them against the consequence of a deficiency.

USE OF ADDITIVES

During the past decade, significant developments in the feeding of farm animals have resulted from explorations of the ways in which chemicals like antibiotics and hormones can be used to increase the productivity and efficiency of food conversion of farm animals. In some instances the action of these compounds has been known for some time but the results could not be applied in practice because the cost was prohibitive. Moreover, considerable research has to be carried out before an additive can be finally recommended. Thus, although beneficial from the standpoint of increased growth, it may have undesirable secondary effects. Another vital factor involving the closest investigation is whether these substances are likely to remain in the meat or get into the milk and possibly endanger public health. The synthetic chemist has in recent years made available hormones and other chemicals at a price sufficiently cheap for them to be used by the farming industry. As long ago as 1896 it was reported that the administration of dried thyroid gland to a lactating cow increased her milk yield. Although interesting, the high cost of the gland made its use prohibitive. When a cheap synthetic product became available, however, it was found that its effect was shortlived. The increment in milk production, noted in the early weeks of the administration of the hormone, was followed by a fall in milk yield greater than would normally occur and the length of the lactation was reduced, thus cancelling out the earlier improvement. Later discoveries have proved of much greater practical value.

HORMONES

It was known as early as 1916 that the fat content of the blood of the hen markedly increased during laying. The explanation came when it was discovered that fat metabolism in the bird is under the control of ovarian hormones and that a marked rise in fat content followed the introduction of oestrin into the blood stream. Hormone injection also produced a marked increase in the blood fat of the male bird. When the synthetic production of oestrogenic compounds was achieved it was found that the cost of these chemicals was reduced to a point where they could be economically used for the fattening of poultry. In 1937 a technique was initiated whereby subcutaneously implanted pellets of diethylstilboestrol, placed generally in the neck, could be used to produce oestrogenic stimulus which led to an increased fat content of the tissues of both chickens and turkeys. The increased fat was evenly distributed to give a superior carcass, the meat being lighter in colour and more tender. These synthetic female sex hormones, particularly stilboestrol and diethylstilboestrol, have been used commercially in the poultry industry for several years, primarily for the fattening of cockerels.

In 1951, nutritionists at Iowa State College observed that lambs on a certain fattening ration made better gains than could reasonably be expected from the diet fed. Investigation revealed traces of hormone activity in parts of the ration. The possibilities of adding stilboestrol, then both the cheapest and most readily available female sex hormone, to the diet of cattle, to

mulate growth and fattening, was therefore investigated. Increased rate of gain and improved feed utilization had previously been demonstrated in pigs and in cattle, but these were accompanied by undesirable effects such as restlessness, riding, elevated tailheads and lowered carcass yield. The Iowa workers found that provided the amount of stilboestrol fed was limited to 10 mg daily the undesirable effects were largely eliminated, but appetite, liveweight gain and efficiency of food conversion were improved. Increased liveweight gains of from 20 to 30 per cent were reported in the final stages of fattening, but the hormone was only given to cattle of over 600 lb live weight. The greatest care was taken to test the meat for oestrogenic residues and it was demonstrated that the meat of beef animals receiving up to 12 mg of stilboestrol daily in their food was entirely free of hormone, provided its feeding ceased 24 hours before slaughter. Pellets of the hormone implanted behind the ear, an organ discarded after slaughter, have proved equally successful, the optimum dose rate for cattle during the final 3 or 4 months of fattening being in the neighbourhood of 60 to 90 mg and for sheep 10 to 15 mg or less. The use of stilboestrol and allied substances for fattening cattle over 600 lb live weight is now widespread in the United States.

The potential use of these hormones in the sheep and cattle industries of the British Isles was considered of sufficient importance by the Agricultural Research Council for trials to be initiated at several research stations in 1954. In this country hexoestrol is considered preferential to stilboestrol, largely because its potency in humans is less.

It seems generally agreed that hormone treatment in ruminants reduces carcass quality due mainly to less fat covering, particularly over the kidneys. The effect of the hormone in the ruminant is very different from that observed in the bird. Instead of increased fat deposition the liveweight gain in cattle and sheep is composed of bone and muscle. There is much better utilization of food protein for muscle development and this is accompanied by greater water retention in the muscle tissue. It follows, therefore, that the beast should have a fair covering of fat before hormone administration starts otherwise the carcass will be excessively lean. Increased liveweight gains of from 20 to 80 per cent have been claimed for cattle in the final stages of fattening; an extra weight of anything from 50 to 100 lb being obtained without having to give extra food. Others report that in order to get the maximum or worthwhile benefit from the use of hormones it is necessary to give correspondingly extra nutrients. In some instances no benefit has resulted from hormone treatment. The lower calorific value of the liveweight increase resulting from hormone administration accounts for the greater inefficiency of food conversion, part of the gain being due to the greater retention of water in the muscular tissue. The hormones are equally effective whether fattening occurs on pasture or on winter diets. An extra liveweight gain of about 0.5 lb per day has followed the implantation of 60 or 90 mg pellets of hexoestrol with cattle grazing during the final 3 months period of fattening. No doubt the protein in the grass is being better utilized and improved bone formation is encouraged by the mineral-rich pasture.

Some undesirable effects are also evident and the development of mammary tissue and growth of teats in females is an unfortunate accompaniment of hormone administration. There is some doubt for these reasons whether the feeding of hexoestrol to sheep will prove commercially sound or acceptable under British conditions.

For further details of the use of hormones in the fattening of beef cattle the reader should consult the Ministry's Bulletin No. 178.*

A factor which may have an important bearing on the use of hormones is the fate of any residual oestrogen from the food that is excreted in the dung and urine. It is contended that these residues may be absorbed by pasture plants from the soil and built up to a dangerous concentration so as to constitute a hazard to animals, particularly sheep, subsequently grazing on such land. Whilst there is no proof that this actually occurs it is a matter that is presently receiving attention at research centres. The danger in this respect is probably less when stock are implanted with the hormone, than when they are fed.

Finally it must be pointed out that the indiscriminate use of hormones such as overdosing of adult animals or administration to breeding stock or young cattle, contrary to established principles, involves considerable hazard and may result in serious loss.

ANTI-HORMONES — THYROID SUPPRESSORS

Compounds like thiourea and thiouracil slow down the rate of metabolism and tend to increase fat deposition in the body. Their benefits are not sufficient to warrant their use on a commercial scale, and they tend to reduce food consumption and depress growth.

ANTIBIOTICS

Although it was reported in 1946 that antibiotics in small amounts stimulated the growth of chicks, little attention was paid at the time to this statement. Interest in the subject really commenced with the discovery of vitamin B₁₂ in 1948 and the subsequent search for sources of this vitamin for feeding to farm livestock. The manufacturers of aureomycin found that the fermentation residues, after the removal of the antibiotic, were a useful source of B₁₂ and in due course, these were marketed for inclusion in pig and poultry feeds. When the growth-promoting properties of the residues, as based on their B₁₂ content, were tested against the pure crystalline vitamin, it was found that the potency of the fermentation residues was distinctly better than that of the pure substance and this was taken to indicate the presence of another unidentified growth factor. It soon became apparent, however, that the second factor was the result of traces of aureomycin left behind. Further tests confirmed that antibiotics were growth stimulants.

Antibiotics gave the greatest stimulus of growth when added to diets composed of all-vegetable foods deficient in B₁₂. It was found that although the necessary amino-acids were present in the latter diets they were incapable of supporting growth comparable with that obtained with animal protein supplements, unless a source of B₁₂ and of aureomycin were added to the diet. Additives of aureomycin residues are now designated Animal-Protein Factor or A.P.F., though the original suggestion that they contained an unknown growth factor is no longer held. During the past decade the use of antibiotics as additives to the diet of chicks, pigs and calves has been the subject of intense research and the work has developed into a search for other growth factors. At present some authorities favour aureomycin and terramycin (oxytetracycline) over penicillin since they are "broad spectrum" antibiotics.

* *Beef Production*. Price 5s. (by post 5s. 5d.) obtainable from H.M. Stationery Office or any Bookseller.

which means they are effective over a broader field of bacterial infection.

The only antibiotics permitted to be included in feeding stuffs in this country are procaine penicillin, aureomycin and terramycin, but there are many others available and the list keeps on increasing.

As might be expected there has been considerable speculation on how antibiotics work. It should be pointed out that the level at which they are included in the diet is many times less than the therapeutic dose employed to combat disease. The obvious suggestion was that antibiotics had an effect on growth and feed efficiency through their action on the micro-organisms in the intestinal tract. In support of this theory, it was shown that chicks and turkeys when raised under aseptic conditions made no positive response to the inclusion of antibiotics in their feed. Furthermore, when the antibiotics are injected and not fed they are found useless as growth stimulants. Several workers have also noted that whereas pigs receiving a diet containing antibiotics when kept in new piggeries made no response over the control pigs, the same diet fed in old unhygienic piggeries resulted in distinctly better growth. The point is still controversial, however, as shown by experiments carried out with inactivated penicillin or penicillin treated in such a way that it will no longer kill bacteria. Some workers claim that inactivated penicillin is still a growth stimulant by virtue of its structure while others have found it useless.

The following points seem to have been established in respect of pigs:

- (1) Antibiotics improve the appetite.
- (2) They are most efficient as growth factors when fed to young animals and are of little benefit to the mature animal.
- (3) Increases in live weight of between 10 and 20 per cent have followed the inclusion of antibiotics in the pre-weaning and the immediate post-weaning diets.
- (4) The antibiotic-fed pigs require about 5 per cent less meal than those receiving none; a saving of between 15 and 20 lb of meal per head is, therefore, achieved.
- (5) Runt pigs usually benefit more than the best pigs. Not all runt pigs, however, will respond to antibiotics.
- (6) Pigs fed antibiotics when weaned are less likely to scour when put on an all-meal diet.
- (7) The feeding of antibiotics has little if any effect on the quality of the carcass.
- (8) The carcasses of pigs fed antibiotics at the level normally employed are entirely free of all trace of antibiotics.

It is possible that the beneficial effect of antibiotics is associated with the suppression of disease at sub-clinical levels, or before it becomes apparent to the eye, so that the well-being of the animal is improved. The effect will be more apparent under rough unhygienic conditions of management and the feeder may see little improvement if the diet is palatable and the pigs are good eaters.

Antibiotics are sold in a form suitably diluted for the farmer to include in his feed mixtures. It is important that they should be thoroughly mixed with the other food ingredients. The recommended rates of addition must not be exceeded.

The level of antibiotic that can be included in a compound feedingstuff in this country is governed by regulations* and is limited to 100 g per ton.

The sale of antibiotics is controlled by the Therapeutic Substances (Prevention of Misuse) Act, 1953, and Regulations made thereunder. They limit sales to those required for medical or veterinary prescriptions and scientific investigations, except in the case of pig or poultry foods, which may contain specified quantities.

The amount actually fed is, however, much lower than this and varies from about 12 g per ton in pig-starter meals to about 5 g in the fattening rations of pigs and poultry. The diet of baby pigs may contain as much as 7.5 g pure aureomycin hydrochloride per 100 lb.

It is unfortunate that there is a trend nowadays towards mass dosages of antibiotics, as practised in the U.S.A., where the level of feeding may vary from 50 to 500 g of antibiotic per ton of meal. The indiscriminate use of antibiotics in feedingstuffs might lead to the spread of highly resistant pathogenic organisms which will render the antibiotics ineffective in combating disease.

How to Buy Feedingstuffs

ONE way in which the tables on pages 96–121 are useful to the owner of livestock is that they show him how to buy the most food value for the least money. Farmers as a rule do not require to buy bulky foods, such as hay, straw or roots, which are grown on the farm and used to form the bulky part of the maintenance ration. Purchases are confined to concentrated foods such as cakes and meals, which are used to supply the productive part of the ration. The figures given in column (13), under the heading Starch Equivalent, give the best measure of the relative productive values of the various concentrated feedingstuffs. The simplest way of comparing the prices at which starch equivalent can be bought in the form of different feedingstuffs would be to divide the price per ton by the figure given in column (13). In this does not really give comparable results, because the price per ton includes not only the food value of the feedingstuff, but the manurial value as well.

MANURIAL VALUES

To obtain really comparable results, the manurial value should first be subtracted from the price per ton. Thus, suppose the price per ton of barley meal is £25 and the manurial value is 13s. the cost of the food value in one ton of barley meal is £24. 7s. The starch equivalent of barley meal is 71, and the cost per unit of starch equivalent in barley meal is £24. 7s. ÷ 71, or 6s. 10d. Again, if the cost of one ton of maize meal is £32, and the manurial value is 12s., since the starch equivalent of maize meal is 78, the cost per unit of starch equivalent in maize meal is £31. 8s. ÷ 78, or 8s. 0½d. Evidently starch equivalent can be bought more cheaply in barley meal than in maize meal at these prices.

The present method of calculating the manurial values of feedingstuffs is based on the recommendations of a Committee constituted in 1945 by the Ministry of Agriculture.* The unit prices of the nitrogen, phosphoric acid and potash in the original feedingstuffs are taken as the following fractions of the unit prices of these manurial constituents in certain selected fertilizers: 30 per cent for nitrogen, 50 per cent for phosphoric acid and 60 per cent for potash. The selected fertilizers are sulphate of ammonia (20.8 per cent N), superphosphate (18 per cent water soluble P_2O_5) and muriate of potash.

* For the full report of this Committee, see *Agriculture* 53, 163, 1946.

50 per cent K_2O). To obtain the unit prices, the subsidy is subtracted from the net price per ton (excluding any early delivery rebate) and an allowance of £1 per ton is added for delivery and spreading. The result is then divided by 20·8, 18 or 60 as the case may be. On the basis of the 1959 prices for these fertilizers, for example, the unit value for the nitrogen of feedingstuffs works out at:

$$\frac{30}{100} \frac{(\pounds 21. 8s. - \pounds 9. 18s. + \pounds 1)}{208} = 3s. 7d.$$

Similarly the unit values of phosphoric acid and potash of feedingstuffs work out at 4s. 10d. and 4s. 3d. respectively. These unit values should be halved when calculating the residual manurial value per ton of consumed feedingstuff after one crop has been removed, and no compensation should be allowed after two or more crops have been removed. Naturally the unit prices for calculating manurial values are subject to modification with any revision of the unit prices of the manurial constituents in the standard fertilizers.

Sufficient data are given in the Tables at the end of this Bulletin to enable the manurial values of a large number of feedingstuffs to be calculated. The percentage of nitrogen is obtained by dividing the percentage of crude protein, as recorded in column (2) of the Tables of Composition, by 6·25, whilst the percentages of phosphoric acid and potash are given in the Table of Mineral Composition. The following example will serve to clarify the method of calculation:

Linseed cake contains 29·5 per cent of crude protein. Its content of nitrogen, therefore, is $\frac{29.5}{6.25} = 4.7$ per cent, whilst phosphoric acid and potash are present to the extent of 1·7 and 1·3 per cent respectively. The manurial value of one ton of linseed cake, on the basis of the 1959 unit prices, works out, therefore, at $(4.7 \times 3s. 7d.) + (1.7 \times 4s. 10d.) + (1.3 \times 4s. 3d.) = 30s. 7d.$ After the removal of one crop, the residual manurial value per ton of linseed cake consumed would obviously be half of this value, namely, 15s. 3½d.

It should be emphasized that values calculated in the foregoing manner are regarded as *average* values, and are to be used only under "fair average" conditions of farm management. Conditions are defined as satisfactory where 'the urine is well conserved and the dung well made, where reasonable precautions are taken against losses in the dung heap, and where the dung is applied to land likely to give normal responses'. Guidance as to the adjustment of the average values, in accordance with varying conditions of management, is provided by the following scheme:

	<i>Feedingstuffs fed to milking cows</i>	<i>Feedingstuffs fed to stock other than milking cows and working horses</i>
(1) Fed directly on the land . . .	Average value . . .	Add one-third
(2) Fed under cover — conditions satisfactory . . .	Average value . . .	Add one-third
(3) Fed in open yards — conditions satisfactory . . .	Subtract one-third . . .	Average value
(4) Conditions unsatisfactory . . .	Subtract up to two-thirds . . .	Subtract up to one-half.

No compensation is allowed for feedingstuffs fed to working horses.

To find the cheapest kind of concentrated food for any particular purpose, ascertain the prices per ton at which a number of suitable feedingstuffs can be bought, subtract from the price per ton of each food the manurial value

per ton, and divide the remainder by the starch equivalent as given in column (14). The result is the cost per unit of starch equivalent in the various foods. Comparison of the prices will show which food is really cheapest.

Feedingstuffs

PASTURE GRASS

Pasture grass is the cheapest and most abundant food on the farm and generally no food is so much wasted. Grass differs in one essential respect from other feedingstuffs used in that its chemical composition and nutritive value are continually changing; they are functions of its stage of growth and therefore to some extent under the control of the farmer. No one set of figures can be taken as representing its nutritive value. Again the composition of grass depends more on management than on the botanical composition or species of grass forming the sward.

CLOSE GRAZING

Young grass of up to four or five inches high, on closely grazed pasture is a protein-rich food comparable in composition with bean meal. It is far too rich in protein to form a balanced diet for any type of stock except, possibly, high-yielding cows. It is a highly digestible food since the cell wall is thin and tender, the cellulose being unlignified, so that the crude fibre is over 80 per cent digestible by sheep. Even in starch equivalent it compares favourably with the oilcakes, and has a further merit of being a rich source of boron forming minerals. Since the dry substance of such grass is a protein concentrate it must be utilized like any other farm protein concentrate, and correctly balanced rations are to be fed in summer as well as in winter. Young grass is also a rich source of the vitamins, the only ones missing being vitamin D and vitamin B₁₂, which the body of herbivora can manufacture.

Naturally close grazing has its drawbacks, the most obvious being the continual defoliation, necessitating a period of recovery, gives a low yield per acre particularly in years of drought. The danger of bloat on such a concentrated and easily fermentable food is also great (though it can be lessened by having a few bales of straw scattered about the pasture, the coarse fodder preventing too much compaction in the rumen).

ROTATIONAL GRAZING

The system of management known as "rotational close grazing" was devised as a means of obtaining greater returns per acre. The essential features of the system are that growth is allowed to continue unchecked for a month and then the pasture is heavily stocked to ensure very close grazing. In practice the precise interval necessary depends on the rate of growth of the grass; intervals between grazings of three or four weeks in the quick growing period of early summer, lengthening out to five or even six weeks in the slow growing period of midsummer, are usually called for. Rotational grazing is achieved by dividing pastures into small enclosures or paddocks, for grazing in succession, or by the modern method of strip grazing, using the electric

acc. Either method ensures a much bigger yield of nutrient food per acre per season than is obtained by continuous or non-rotational close grazing. Close grazing of the paddocks or strips is essential to prevent the herbage becoming coarse and "foggy" with a consequent deterioration in nutritive value at the end of the season.

It will be appreciated that with monthly intervals of unchecked growth the actual monthly yield of grass will vary considerably during the growing season. Every farmer is familiar with the quick growing flush period when the grasses tend to shoot up flowering stems. During the fore-flush and post-flush periods of the season the herbage should be of an essentially leafy character and retain its protein-rich nature. With the advent of the flush period, however, the protein content of the grass falls though its digestibility and starch equivalent remain quite high. Investigation has shown that 100 lb of the dry substance of the herbage during the flush period should provide 14 lb of digestible protein, and around 60 to 66 lb of starch equivalent. As will be shown later, a cow consuming 30 lb of dry matter of such herbage will receive almost the exact amount of starch equivalent and digestible protein to meet her needs for maintenance, and also for the production of five gallons of milk. The herbage contains much more protein than the fattening animal requires. As much as 54 per cent of the total yield during the season may be produced during the two months of the flush period with a digestible protein content of about 13 per cent.

During July and August the protein content of the grass will improve but the yield will not be so abundant at this stage. During September the herbage becomes still richer in digestible protein. Control of grazing is particularly necessary when liberal use is made of nitrogenous and other fertilizers.

EXTENSIVE GRAZING

The system of grazing that is still widespread in Great Britain is one which ensures that the pasture always carries a fairly good bite, without any attempt at close grazing. Under such a system the pasture, after midsummer, falls off continuously in feeding value owing to the gradual accumulation of dead and coarse herbage. With the advent of autumn the bulky herbage may be little better than good or even medium quality hay. Topping the pasture with a mowing machine will bring about some improvement besides helping to control weeds.

Winter herbage compares unfavourably in respect of composition, digestibility and starch equivalent with spring grass of similar height and stage of growth. Winter grass despite its leafy character undergoes a considerable degree of lignification.

In some parts of the country cocksfoot-lucerne mixtures have gained considerable popularity both as regards yield and improved chemical composition of the herbage. The main distinction in nutritive properties between lucerne and grass is the readiness with which the young lucerne plant develops, and the earlier stage of growth at which the fibre becomes lignified, particularly that of the stem portion of the plant, the leaf not being affected to any significant extent. The cocksfoot-lucerne sward therefore needs more careful management than the ordinary grass sward. The drought-resistant character of the lucerne plant, and the fact that in the young stage lucerne may contain up to 30 per cent of crude protein on the basis of dry matter,

makes it, however, a most valuable ingredient for grazing or for making into silage.

MEADOW HAY

In years gone by three types of hay were commonly recognized in farm practice. One was the produce of permanent grassland, known as meadow hay, though in fact it often came from fields remote from riverside meadows. It contained a large number of species of grass, small quantities of clovers and miscellaneous herbs. At the other extreme came hay made from pure stands of red clover.

Intermediate in composition between these two was "seeds" hay, derived from short term leys, and usually consisting mainly of rye grasses, with variable quantities of red clover. It was richer in protein and lime than meadow hay, but tended to be more fibrous and less digestible than meadow hay, and consequently had a lower starch equivalent.

Since World War II ley farming has become general. Many leys are sown down without any red clover, and in any circumstances the botanical composition of a ley changes as it ages; the composition of a long ley tends to be approximate in its later years to that of a permanent meadow. As hay is now made from leys of all ages no clear distinction can be drawn between "seed" hay and meadow hay. In this bulletin, therefore, all hays except clover and lucerne are classed as meadow hay.

Samples of meadow hay taken from farms in different parts of the country have shown the wide variation that occurs in the composition and feeding value of this coarse fodder. Variations in crude protein content of from 4 to 12 per cent and in crude fibre from 22 to 33 per cent have been recorded. The starch equivalent varied from under 25 to over 40 and the protein equivalent from 1 to 8 per cent. It is important that the farmer should appreciate the nature of the factors that cause this great variation in composition and nutritive value of hay.

A factor of primary importance is the stage of growth of the herbage, whether the grasses are just at the flowering stage or long past it. There is always a tendency to sacrifice quality for bulk; moreover, wet weather often delays cutting beyond the date on which the farmer planned to cut. The earlier the hay is cut the richer it will be in protein and minerals, and the fibre will be less woody so that digestibility will be better.

Considerable losses also take place in the actual process of haymaking. These losses may be due to respiration, mechanical action and fermentation. After the herbage has been mown, the cells of the green plant material continue to live for some time and their respiratory activity causes a portion of the carbohydrate of the crop to be oxidized to carbon dioxide and water. This type of cell activity implies a loss of starch equivalent. Conditions of quick drying, as when tripods are used, are an advantage in reducing this type of loss to a minimum since desiccation stops respiration.

During the drying and curing of the mown herbage the leaf tends to dry out before the hollow stem and consequently becomes brittle and breaks off easily. The mechanical handling of the crop should therefore be reduced to a minimum. Bad weather, particularly when the hay is nearly dry, has a depressing effect on both palatability and feeding value. The sugars together with the soluble phosphates and chlorides are most affected by leaching.

Some further losses occur after the crop has been carted due to the host of micro-organisms that flourish in the stack. If the crop is carted on the green moist side the conditions will be favourable for the bacteria to attack the remaining carbohydrates and the more digestible fibre forming organic acids, and with the production of considerable heat. Heating in the stack is a familiar phenomenon and its intensity is a measure of the activity of the bacteria. The subsequent action of the thermophilic cellulose-splitting bacteria may cause the temperature of the stack to rise to such an extent that the proteins are thereby rendered indigestible with a serious lowering of feeding value. Similarly, if the hay is baled in too moist a condition it will become mouldy and of low feeding value. The losses in haymaking, even under favourable conditions, amount to as much as one quarter or one third of the nutrients originally present in the green herbage. The making of hay by barn drying results not only in better hay but also in greater yield of nutrients per acre.

LUCERNE HAY

Lucerne hay constitutes a most valuable protein-rich roughage. Its composition and feeding value are greatly influenced by its stage of growth. A carefully-cured lucerne hay, from a crop cut in half flower, contains not only as much starch equivalent as good meadow hay, but is two or three times as rich in digestible protein. About 18 lb of such hay not only provides the necessary nutrients for the maintenance of an average cow but also sufficient protein for maintenance and the production of 3 gal of milk. After it has reached the full flowering stage the plant then deteriorates rapidly in digestibility, the stems becoming hard and woody.

SAINFOIN HAY

Another leguminous crop which is also a good source of protein and lime is sainfoin hay. When cut before flowering the hay will contain about 15 to 16 per cent of crude protein on the dry matter basis.

GRASS SILAGE

One alternative form of conservation of grass is to make grass silage.* High quality grass silage should contain on the basis of dry matter 15 per cent or more of crude protein. Such silage is made from young leafy grass or cocksfoot-lucerne cut at a distinctly younger stage than is customary for hay making. At its best 20 to 30 lb of high protein silage will replace the usual balanced concentrates in milk production. Its main disadvantage is its bulkiness and its smell. It is difficult to be precise when dealing with the feeding value of silage since the dry matter varies between the top and bottom of the silo as well as from the outside to the centre. It is generally reckoned that 4 tons of grass will produce 3 tons of silage of the same dry matter content — a loss of 25 per cent. To this must be added the loss resulting from spoilage by moulds at the top and sides, and also from faulty consolidation. The loss, therefore, though only half that involved in hay making is considerably higher than in producing dried grass of the same quality. There is no doubt that making silage is now a much less risky

For full details of the various methods of silage making see Bulletin No. 37, *Silage*. Price 6d. (by post 3s. 11d.) obtained from H.M. Stationery Office or through any bookseller.

proposition than it was a few years back. By chopping, bruising and minding and particularly by wilting, it is possible to make good silage without additives. Experience shows, however, that the addition of molasses or shown more recently, sodium metabisulphite is an additional safeguard, and the making of good silage is now almost foolproof. A farmer can add considerably to the productivity of his pastures by making silage and also economize in oilcakes. Among recent innovations has been the making of baled silage using the pick-up baler, since this avoids the labour of cutting out

ARTIFICIALLY-DRIED YOUNG GRASS

Since the dry matter of young grass is a protein-rich concentrate it is natural that proposals should be put forward for conserving such grass for use in winter. Dried grass is now obtainable in the form of bales, meal cubes. The modern grass drier is able to dry down grass with very little sacrifice of feeding value, and without the losses incidental to the process of hay making.

A good quality of dried young grass, assuming a moisture content of 10 per cent, should contain nearly 60 per cent of starch equivalent including at least 12 per cent of protein equivalent. Unfortunately a good deal of the dried grass made during the earlier years fell short of this high standard. The Fertilisers and Feeding Stuffs Regulations specify that in order to qualify for the title of dried grass the herbage should contain 13 per cent of protein, calculated on the 10 per cent moisture basis, an inferior grade containing between 10 and 13 per cent protein being designated dried grass (maintenance quality). On a number of farms grass-drying plants have been installed mainly for the production of super-hay so as to avoid having to make hay, and also to provide a less bulky fodder for high-yielding cows and for calves.

The regional nutrition chemists of the National Agricultural Advisory Service have suggested dividing dried grass into the following categories for evaluation:

<i>Category</i>	<i>Crude protein (90 per cent dry matter basis)</i>	<i>Amount required for 1 gal average milk</i>
A	17 or over	5 lb
B	15-16.9	5.5 lb
C	13-14.9	5 lb grass + 0.5 lb high protein cake or 4 lb grass + 1 lb medium protein cake
D	11-12.9	4 lb dried grass + 1 lb high protein cake or 3.5 lb dried grass + 1.5 lb medium protein cake
Super hay	Under 11	Maintenance food

For feeding to ruminants it is preferable to bale the dried grass as it becomes very dusty on grinding. The cost of production can be considerably reduced by previous wilting, the lowering of cost far outweighing any disadvantage suffered by the loss of carotene. There is considerable scope for co-operative grass drying in this country.

STRAW

The straw of cereals constitutes a bulky fodder containing a high percentage of indigestible fibre and negligible amounts of digestible protein and oil. Its feeding value lies in the contribution it makes towards the digestible carbohydrates and fibre in the ration. The percentage ash is fairly satisfactory, but its richness in silica renders it of little value. For ruminants its bulk may in certain circumstances be an asset, since a certain amount of fibre aids mastication and regurgitation of the food and prevents constipation and bloat.

Oat straw constitutes a more valuable fodder than either wheat straw or barley straw. The feeding value of straw is conditioned by the stage of maturity of the crop at harvesting and oats are usually cut before they are fully ripe and before the sugars and other nutrients have been completely transferred from the stem to the seed. Straw from malting barley that has become fully ripe, and wheat straw, are of little feeding value and should never be chaffed but always fed liberally in the rack for the animals to pick over and eat the more succulent portions. When barley is used as a nurse crop, so that the straw includes some clover and grasses, and when cut earlier than for malting, it may have a value equal to oat straw. When oat straw bulks largely in the ration, part of it is often mixed with pulped roots and with chaffed kale and the mixture allowed to stand for some hours before feeding: this leads to a softening of the hard straw and an enhancement of its palatability.

Straw is best utilized for feeding to store cattle and many bullocks are over-wintered on straw, roots and a little cake, to be fattened on grass the following summer. Oat straw is a great saver of hay in winter feeding, and one lb of oat straw plus 2 lb of chaffed kale will supply the starch equivalent and digestible protein in 1 lb of good hay. Up to 10 lb of straw can be included in the diet of fattening bullocks to supply about 2 lb of starch equivalent. It is too bulky for dairy cows yielding more than one to one and a half gallons of milk.

Leguminous straws are often harvested in a damp condition so that they become mouldy and dusty, and should only form about one-third of the coarse fodder fed. The pea vine or pea haulm and pea pod, from the growing of peas for canning, is, however, a very superior coarse fodder and can be made into silage rich in protein and lime. The crude protein may be as high as 15 per cent and the percentage lime over 2 per cent, both on the basis of dry matter.

GREEN FODDERS OR FORAGE CROPS

GREEN LUCERNE

When this forage crop is grown for cutting under the soiling system it may yield as much as 15 to 20 tons of green food per acre per season. Its main characteristics are that the lucerne plant is drought resistant, rich in protein and an outstanding source of lime. It can, therefore, play a particularly important role during dry summers in maintaining milk yield when pasture grass and other succulent foods are scarce, though as stated earlier, it tends to become lignified and woody very soon after it attains the flowering stage, and then deteriorates rapidly in feeding value. When thoroughly established

it is advisable to take 3 or 4 cuts per season. About 24 lb of green lucerne provide sufficient nutrients for 1 gal of milk. One lb of lucerne hay supply up to 3 oz of lime.

CABBAGES

Cabbages constitute a palatable and nutritious food for stock and are specially valuable for feeding to dairy cows, when the grass is scarce. They should be planted in late April or early May for cutting in mid-August. A second planting in mid-May will be mature in late August or early September. A third planting in early June will provide valuable fodder in early October. Generally speaking, in the South, summer and autumn cabbages can follow other crops cleared by the end of April. Winter cabbages and savoys follow the earliest cleared summer crops. In the North brassicas occupy the land for a longer period. Details of suitable varieties to sow are given in the Ministry's Bulletin 132*

The leaf is a good source of digestible protein and minerals; dairy cows can deal efficiently with up to 60 lb per day. Larger quantities may lead to taint in the milk.

MARROWSTEM AND THOUSANDHEAD KALE

By growing kale a farmer provides at a low cost a heavy yield of nutritious and succulent food. Yields of 20 tons per acre, or more, are common and kale is highly relished by cattle and sheep. One ton of marrowstem kale (13.8 per cent dry matter) supplies as much starch equivalent as 1.2 tons of swedes (11.5 per cent dry matter), the kale moreover providing about 10 lb of protein equivalent per 100 lb dry matter as against about 6 lb in swedes. Kale is therefore much superior as a provider of protein. Marrowstem kale is suitable for carting off and feeding in yards or on grass, from August to the end of December, and the fact that the plant stands up well from the ground and the edible portions are always clean make it most suitable for soiling by cattle or sheep. It can also be consumed *in situ*, by using the electric fence, to save the labour of cutting. Thousandhead kale is generally not such a heavy yielder, but is reputed to be more winter-hardy than marrowstem kale. Half of the dry matter in the marrow from the stems is composed of sugar and this ensures the right type of fermentation when kale is chopped and made into silage. With very leafy kale, however, some consider it an advantage to add about a gallon of molasses per ton of chopped kale, to avoid any risk of sour silage. Although the losses in making silage from such a succulent crop may be as high as 30 to 50 per cent of the dry matter, it is considered worth while in regions where severe winter conditions are apt to cause a considerable loss of leaf, and where cutting and carting would be laborious and unpleasant, and where grazing is impracticable. Young kale may contain as much as 3.7 per cent of lime and 0.7 per cent of phosphate on the dry matter basis. A moderate yield of 15 tons of marrowstem kale means a production of 3,100 lb of starch equivalent per acre compared with about 1,300 lb from the grain of an average crop of barley.

Kale is rapidly assuming a role in winter feeding not dissimilar from that of grass in summer and is one of the most attractive of bulky farm foods as a saver of concentrates.

* Bulletin 132, *Cabbages, Brussels Sprouts and Other Green Crops*. Price 3s. (by post 3s. 4d.) obtainable from H.M. Stationery Office, or through any bookseller.

GREEN MAIZE

the south green maize provides a useful fodder during late summer and early autumn for feeding on pasture. It yields a very heavy crop — up to 10 or 17 tons — of succulent green food which is usually cut in the early flowering stage when the dry-matter content is 16 to 18 per cent. Its main advantage is that the protein equivalent is distinctly lower than in leguminous fodders.

VETCHES

Vetches are either grown alone or in admixture with peas, beans, oats, barley or rye. They produce a crop of digestible nutritious food rich in protein, but owing to the weak stems the plant becomes laid in damp weather and is apt to rot at the base. A supporting crop is, therefore, sown and oats are probably the most favoured since they generally shoot just before the vetch whose tendrils then cling to the oat straw for support, and both plants come to maturity at the same time. The bean crop, on heavy soil, produces a great weight of excellent fodder and is a good supporting crop. Mixtures of spring beans, vetches, peas and oats give heavy yield of green forage for soiling or for making into silage.

SUGAR-BEET TOPS

The tops consist of the green and yellowing leaves and the crown. The leaves are rich in protein and low in fibre and the crown supplies carbohydrates. The average yield of tops is about 8 ton per acre and they provide a useful feed for the flock from October to January though it is advisable to feed a little hay, which helps rumination. An acre of tops should provide sufficient feed for 100 sheep per week. A ton of tops when folded is equivalent in feeding value to a ton of swedes or mangolds for cattle or sheep. The tops however will be much richer in protein. It is essential that the tops should be reasonably free from soil contamination and that they should be allowed to wilt for a week before feeding since they contain oxalic acid and oxalates. The oxalic acid content shows considerable seasonal variation and to graze the tops, so as to facilitate lifting, is risky. Fortunately the bacteria in the rumen can partially destroy oxalic acid and reduce the danger of toxicity, but it is much safer to wilt beforehand. An alternative safeguard is to sprinkle 1 oz of finely ground chalk over 250 lb of tops so as to render the oxalic acid insoluble. Care should be exercised in feeding the tops to dairy cows, otherwise a fishy unpleasant taint may develop in the milk. The amount should be limited to about 60 lb fed immediately after milking, and preferably on pasture.

ROOTS AND TUBERS

Roots and tubers are "watered" carbohydrate concentrates, the main constituent in roots being sugar, whilst in tubers such as potatoes, the reserve carbohydrate takes the form of starch. Turnips contain only 8 to 9 per cent of dry substance; swedes 10 to 14 per cent, mangolds 10 to 15 per cent, sugar beet 24 to 25 per cent and potatoes vary between 20 and 25 per cent. A comparison of the chemical composition of the dry matter shows a striking resemblance between barley meal and roots and tubers, thus emphasizing their carbohydrate-rich character. They are poor sources of protein, oil and mineral matter. On the basis of starch equivalents it can be shown that 1 ton

of swedes (11.5 per cent dry matter) is of equal feeding value to 2.2 cwt barley meal.

Mangolds should not be fed immediately after harvesting on account of their scouring action, caused by the presence in the root of small amounts of nitrate. Storing in the clamp until the new year will ensure that enzymes have transformed them into innocuous asparagine. Mangolds are less prone to taint milk than other roots. They are also used for feeding to fatten and store cattle and scattered on the pasture in spring to be eaten by ewes and lambs, for which purpose they are ideal to balance the protein-rich grass.

Swedes and turnips should be fed immediately after milking as otherwise they are liable to taint milk. Swedes are a favourite ingredient in the diet of fattening cattle, but they must be supplemented with protein and minerals. In days gone by it was customary in Norfolk to allow fattening cattle all the roots they would eat. Under these conditions the animals would consume 0.75 to 1.5 cwt of roots per day. Probably feeding not more than 50 lb of roots is more economical. Sheep folded on roots will need a little legume hay and concentrates.

POTATOES

Out of the 24 per cent dry substance present in potatoes as much as 20 per cent is starch. It is apparent, therefore, that almost their sole function is to provide digestible carbohydrates. The protein, oil and mineral contents are decidedly low. Incidentally about one-half the crude protein is present in the form of amino-acids, asparagine and ammonium salts, the other half being true protein.

Potatoes are fed in replacement of roots and for this purpose 1 lb of potatoes may be regarded as being equal to 2 lb swedes or mangolds. The potatoes must be reasonably clean and free from disease and must be introduced very gradually, as they will otherwise cause serious digestive disturbance. Many feeders prefer to pass them through the root slicer to avoid any danger of choking. Potato sprouts should on no account be fed as they contain a poisonous glucoside, solanin, which may amount to 5 per cent in the young shoots, and cause a serious lowering of milk yield. For the same reason tubers that have turned green are risky to feed. For store cattle up to 40 lb potatoes may be gradually introduced to replace 80 lb of swedes. For dairy cows a suitable maximum is 20 lb per head daily as they have a slightly acrid and bitter taste, and have a laxative action.

When potatoes are used to replace barley meal in the diet of pigs and poultry it is advisable to cook or steam them, and 1 lb of cereal meal is equivalent to 4 lb cooked potatoes. Artificially dried potatoes are manufactured in the form of flakes and slices, in which form the starch is cooked and also as cosettes or meal which are raw or uncooked.

Surplus potatoes may also be conserved on the farm by the process of ensilage. This may conveniently be achieved in a stack or pit, in conjunction with grass or other green crop, a 3 ton layer of grass herbage alternating with a 1 ton layer of small tubers. Owing to the heat produced by the fermenting grass the potatoes came out in a floury and semi-cooked condition.

A second method involves steaming the washed potatoes and then pressing them firmly into a concrete-lined pit so as to exclude air and finally covering with a layer of earth. The cooked potatoes keep wholesome in the pit over a long period.

WET AND DRIED SUGAR BEET PULP

When the pulp is removed from the extractors it contains 95 per cent of water which is reduced by pressing to 85 per cent. In this form some is sold as wet sugar beet pulp but the cost of transport tends to restrict its use to farms in the vicinity of sugar factories. Its keeping properties are also poor and it should be used quickly in much the same manner as mangolds.

The dried sugar beet pulp is a bulky, highly digestible and essentially carbohydrate-rich food. It may be used as a substitute for roots in the maintenance ration of cattle, 1 lb of the dried pulp being equivalent to 7 to 10 lb of mangolds. Dairy cows may receive up to 8 lb, fattening bullocks up to 12 lb, but it is advisable to soak the pulp in twice its weight of water, so as to soften it before feeding.

The dried pulp being a concentrate can replace cereals in production rations. 1 lb dried pulp = 1 lb crushed oats = 0.9 lb wheat or barley = 0.8 lb maize.

Although pigs digest the pulp quite efficiently it is too bulky for feeding any amount to fattening pigs. It may be used in moderation for feeding sows.

MOLASSED SUGAR BEET PULP

In most factories, the wet beet pulp is mixed with a proportion of beet molasses before drying, the product being sold as molassed sugar-beet pulp. It contains 15-20 per cent of sugar and has a feeding value about equal to the ordinary dried pulp.

BEET MOLASSES

The syrupy residue remaining after crystallization of the sugar contains about 30 per cent of water and about 60 per cent of sugar. The ash is largely potash salts with little lime or phosphate. These alkaline salts give it a laxative action somewhat resembling roots. Molasses is utilized to improve the palatability of chaff or palm kernel meal, as well as in the making ofilage. Its nutritive value is not high.

CEREAL GRAINS

The home-grown cereals are limited to wheat, barley, oats and rye. Imported cereals include maize, rice, millet and dari. The cereal grains are all rich in carbohydrates, present mainly in the form of starch, but relatively poor in protein which amounts to around 10 per cent. The oil content of wheat and barley is low but oats and maize contain a fair amount of this constituent. The high content of fibre in oats is a consequence of the inclusion in the grain of the fibrous husk which may form as much as 23 to 25 per cent of the total grain. The presence of the coarse fibrous husk is also reflected in the lower starch equivalent of this cereal grain. Naturally after the removal of the husk the resultant dehusked oats — the oat meal or porridge oats used in the kitchen — have a fibre content and starch value comparable with wheat. Barley lies between oats and wheat in respect of fibre content since, in this instance, the husk forms only 10 per cent of the grain.

The cereal grains are seriously deficient in lime and chlorine, but contain a satisfactory amount of phosphate.

OATS

Oats are the safest of all the cereals and can be fed liberally to all classes of stock with the exception of pigs. The large amount of husk makes them rather unsuitable for very young pigs, and they can be eaten more readily by older pigs if they are finely ground in the hammer mill. Crushed oats are excellent for ruminants, their starch equivalent being 60.

BARLEY

Barley is pre-eminently a food for pigs since its low oil content leads to a high quality carcass and its percentage of fibre is near the optimum for pigs. There is some prejudice among dairymen against the use of barley on the ground that it is said to have an unfavourable influence on milk yield. No doubt this is associated with the glutinous character of the grain, and the tendency to form a doughy mass in the digestive tract, causing mild bloat or indigestion. This can be overcome, however, by feeding the grain in a coarse crushed condition in admixture with foods of an open or light texture such as bran or crushed oats. The starch equivalent of barley averages about 71.

WHEAT

Wheat, on account of its heavy glutinous character, needs to be used more carefully than some of the other cereals. It should never be ground to a fine meal for feeding to farm animals because of its tendency to become pasty when chewed, which makes it difficult to masticate and to swallow. Some cows are unable to take more than 4 to 6 lb of wheat per day without suffering "feed sickness" or going "off feed". Definite symptoms of indigestion with depression of milk yield may be evident, but although severe it is generally only temporary, the cow fully recovering in two or three days. The precautions necessary in feeding wheat are to introduce it gradually, and to feed it coarsely ground even to pigs; it may be incorporated with oats or bran or give a concentrate with an open texture. Ideally, the grain should be rolled to a flaky condition resembling bran. It has the same starch equivalent as barley.

RYE

Rye is less palatable to stock than other grain, and is more liable to give rise to digestive disturbances. It must be fed with care, and only as a part of the grain ration. For feeding to ruminants it should be crushed, rolled or coarsely ground. Some authorities recommend the inclusion of up to 40 per cent of crushed or ground rye in milk mixtures in replacement of barley meal. Against some pig feeders prefer to scald rye before feeding. In any case it should form less than half the cereal ration. The same precaution is necessary when it is included in poultry mashes.

MAIZE

Maize has a higher feeding value than barley meal, its starch equivalent being around 80. It is, therefore, a very valuable ingredient in milk mixtures for high-yielding cows to keep down the bulk. It may contain up to 5 per cent of oil and, therefore, the amount fed to bacon pigs must be limited to about 30 per cent of the ration, or less in the finishing stages, to avoid an oily, soft carcass with a yellowish colour.

Flaked maize is made by cooking the grain to soften it and then passing it between hot rollers to produce flakes. It is finally dried in a current of hot air. The thin crisp yellow flakes are almost wholly digestible and form a valuable concentrate for inclusion in the rations of young animals.

WHEAT OFFALS OR WHEATFEED

In the interval between the wars the old term "millers' offal" was replaced by wheatfeed; coarse middlings became known as fine wheatfeed, and fine middlings as superfine wheatfeed. Home-produced coarse middlings were later standardized and marketed under the description of "weatings", with a guarantee of not more than 5.75 per cent crude fibre, whilst the old fine middlings could be bought under the name of superfine weatings, with a guarantee of not more than 4.5 per cent crude fibre. The pre-war rate of extraction of flour from wheat was about 70 per cent. The milling of 100 tons of wheat gave rise to about 70 tons of flour and 30 tons of wheatfeed of which the bran fraction amounted to 10 tons and the middlings to 20 tons.

With the introduction of the "national wheat-meal loaf" in 1942, the rate of extraction went up to 85 per cent, and the 15 tons of wheatfeed were divided into 10 tons of broad bran and 5 tons of fine bran. The fine bran was coarser than middlings and its crude fibre content was almost as high as in bran. Production of the "national flour" of 80 per cent extraction ceased with the abolition of the bread subsidy in September, 1956, and whiter flours at lower rates of extraction have taken its place. It follows that wheatfeed comparable in composition and feeding value to the pre-war grades, have now again become available to pig and poultry keepers.

Quite recently the pre-war weatings with a guarantee of a maximum of 5 per cent crude fibre have again become available and are being marketed under the old name.

The wheatfeeds are more oily and fibrous, and richer in ash and protein than whole wheat.

BRAN

Although the feeding value of bran is low, its starch equivalent being only 43, there is a high demand from feeders owing to its well recognized physical properties. Thus when made into a mash with warm water, it acts as a mild laxative, but when fed dry, it tends to correct scouring. Bran frequently forms 10 per cent of the diet of farrowing sows, but is rather fibrous for use in the ration of fattening pigs. It is a balanced food for milk production, but its bulkiness is such that it requires 6 lb to provide the nutrients required for 1 gal of average milk. Bran is very rich in phosphate, but lacking in lime and chlorine. It is a good source of vitamins B and E.

COARSE MIDLINGS OR FINE WHEATFEED

The feeding value of middlings is higher than bran as it is less fibrous and richer in starch equivalent and digestible protein. Its palatability and light texture makes it very desirable for inclusion in the diet of weaners, and also for inclusion in milk mixtures. It is a good source of vitamin B₁.

LEGUMINOUS GRAINS

The home-grown concentrates are in general rich in carbohydrates relatively deficient in protein. The leguminous seeds such as beans and peas on the other hand, are fairly rich in protein, and moreover contain a large proportion of starch. Beans and peas have a starch equivalent of 66 and 62 respectively, with a digestible protein content of 20 per cent.

BEANS AND PEAS

For feeding to ruminants, beans and peas should be crushed or cracked, for pigs and calves they should be finely ground. The low oil content of bean meal promotes an excellent quality of fat in the bacon carcass, but a deficiency in minerals, particularly lime and chlorine, must be corrected. It is interesting to note that peas and beans are richer in digestible protein than palm kernel cake, coconut cake and undecorticated cottonseed cake.

VETCH SEED

Experience in feeding vetch seed is more limited than with peas and beans, which it closely resembles in composition. Vetch seeds are less palatable as they contain a bitter principle which may taint milk, though after a period of feeding the undesirable taint is said to disappear. Continental workers recommend steaming the seed for about 10 minutes before feeding to remove the bitter principle and render the seed more palatable.

BARLEY BY-PRODUCTS

The best known by-products are brewers' wet grains, brewers' dried grains, distillers' grains and malt culms. In the process of brewing or distilling carbohydrates are utilized to produce alcohol so that the grains when dried are richer in protein and fibre than barley. Distillers' grains differ from brewers' grains in being less fibrous and richer in protein and may contain grains other than barley.

The wet grains readily turn sour and mouldy if left exposed to the air. To preserve them in a wholesome condition they should be stored under air-tight conditions, or by adding a little common salt (14 lb per ton) followed by hard trampling. The grains are balanced for milk production. It is recommended by some authorities that the amount of wet grains fed should be limited to 25 lb per cow, and that a mineral mixture composed of equal parts of sterilized bone flour and ground chalk should be added at the rate of 1 lb per 100 lb wet grains.

The dried grains contain 18 per cent of protein and 15 per cent of fibre and are not suitable for pigs. They resemble bran in nutritive value but lack its special properties. They are fed to cattle at the rate of about 6 lb per head per day and are very palatable.

Malt culms consist of the dried sprouts and rootlets of the malt. They contain 14 per cent of fibre and 24 per cent of protein of which one third is present as asparagine. Again they resemble bran in nutritive value.

MAIZE BY-PRODUCTS

These are by-products from the manufacture of starch. They comprise maize germ cake or meal, maize gluten meal and maize gluten feed. The maize germ is rich in oil and gives a feedingstuff high in starch equivalent with moderate protein content. The maize gluten separated from the starch gives

concentrate containing 35 per cent of protein. Maize gluten feed is produced from maize gluten meal by adding to the latter the finely ground maize husk removed in the initial stages of starch manufacture. Maize gluten feed contains only 23 per cent of protein and is balanced for milk production.

OILSEEDS, OILCAKES AND EXTRACTED MEALS

The oilseeds are grown mainly in tropical countries for the sake of the edible oil they contain. Oilcakes and extracted meals are the residues remaining after the extraction of the greater portion of the oil from these seeds and their hulls. Fortunately the residues are generally rich in protein and are purchased to balance home-grown feedingstuffs.

The old method of removing the oil by hydraulic pressure is now obsolete, because it left too much of the valuable oil in the residue and was expensive in labour. The modern method is to use the expeller screw-press or to extract the oil by means of an organic solvent. The expeller process is continuous, the prepared seed being forced by a powerful screw along a narrowing or constricting tube so the oil is squeezed out. The residue is in the form of broken flakes or fragments and usually has an oil content of 5 to 6 per cent. Some charring may take place owing to the heat produced in the expeller. In the extraction process a non-inflammable volatile solvent such as trichloroethylene, is allowed to percolate through the coarsely-ground prepared seed so that it dissolves most of the oil, the residue containing no more than 1-2 per cent. Considerable care is taken to recover as much as possible of the volatile solvent and to ensure its complete removal from the extracted meal.

Sometimes the procedure is more complex in that the husk or hulls of the seed have to be removed before extracting the oil, thus giving a residue termed decorticated cake or meal.

The stockfeeder must therefore distinguish between expeller nuts or meal, extracted meal, undecorticated cake or meal, decorticated cake or meal and extracted-decorticated cake or meal. The method of preparation may influence considerably the feeding value.

LINSEED

Linseed is a home-grown seed containing 37 per cent of oil, 24 per cent of protein and with a starch equivalent of 119. When used in calf feeding treatment of the seed with boiling water is necessary to safeguard against poisoning from cyanogenetic glucosides, present in unripe linseed (feeding as a baby food to adult stock largely eliminates this danger). For cattle the seed should be ground in a hammer mill with an absorbent food like bran to prevent loss of oil. The slimy mucilage of linseed has a soothing effect on the bowels of sick animals.

LINSEED CAKE

Linseed cake is a medium-protein-rich cake containing about 25 per cent of digestible protein and has a starch equivalent of 74. It is a very safe cake to feed and is prized for the bloom it gives when included during the final month in the finishing diet of fat cattle. It is not often used in pig feeding because it is apt to produce an oily soft carcass.

COTTONSEED CAKES

There are two kinds of undecorticated cottonseed cake known as Egyptian and Bombay, corresponding to two kinds of cottonseed. Most of the cotton

lint is removed from the Egyptian seed in the ginning process, giving undecorticated cake almost free of cotton fibre, but with the Bombay seed the lint covers the whole seed and the undecorticated cake may contain considerable amount of lint. The astringent property of undecorticated cottonseed cake makes it a valuable feedingstuff to prevent scouring on lush pasture, or when heavy allowances of roots are given.

The dehulled seed gives a cake of much higher feeding value, the decorticated cottonseed cake containing 40 per cent of crude protein, and with starch equivalent of 68 and a protein equivalent of 34.

Cottonseed meal is not recommended for pigs or calves because of the danger of "gossypol" poisoning.

During the past few years specially processed cottonseed meals of low free gossypol content have been made available commercially in the U.S.A. but these are not yet available in this country. Cottonseed meal is quite satisfactory for feeding to cattle.

GROUND-NUT CAKE (*also known as earth-nut, monkey-nut or pea-nut*)

Decorticated ground-nut cake is unusually rich in crude protein containing as much as 50 per cent and should, therefore, be used in moderation. Provided it is properly balanced it forms a safe and valuable food for all types of stock. Extracted decorticated ground-nut meal and minerals are used as a substitute for white fish meal in the diet of pigs.

SOYA-BEAN CAKE

This is a high-protein cake containing about 40 per cent of crude protein. Extracted soya-bean meal, containing only 1.5 per cent of oil, is probably the most commonly used vegetable-protein concentrate for feeding to pigs and poultry. The soya-bean proteins are unique in that a moderate degree of heating improves their feeding value. Several theories have been put forward to account for this, the most recent being that raw soya beans contain a toxic protein "soyoin" which retards growth. On heating, the soyoin becomes denatured and is then digested by pepsin. Certain trypsin inhibitors of a protein-like nature, have also been isolated from raw soya beans and are only digested by pepsin after heat treatment. Commercial samples of soya-bean cakes and meals are now heat treated. Soya-bean proteins are deficient in methionine for feeding to poultry.

PALM KERNEL CAKE

Palm kernel meal is not as palatable as some of the above oilcakes so that its introduction into the ration calls for both skill and patience. Because of its dry and gritty nature it tends to produce excessive salivation and it must be introduced into the ration gradually. It is often used to steam-up dairy cows since it can then be introduced very slowly and after a time cattle will entirely lose their objection to its taste and consume it readily. The cake is eaten most readily in the form of lumps rather than meal and some manufacturers add molasses to increase its palatability. It is relatively rich in fibre containing 13 per cent.

Palm kernel cake is a low-protein cake balanced for milk production and it is very safe to feed.

COCONUT CAKE

The dried fleshy interior of the coconut is known as copra. The kernels are dried and extracted to remove the valuable coconut oil. Should the copra become rancid during the drying process, the coconut meal will have poor palatability, and this is one of its disadvantages. The meal must also be stored in a dry place as it tends to take up moisture from the air and then moulds. For the same reason it is desirable that the meal should be soaked in water before feeding.

Coconut cake is a low-protein cake but has a starch equivalent of 75. It is a balanced food for milk production and gives a hard fat which is apt to become tallowy if the amount fed exceeds 3 or 4 lb per day. When incorporated in a diet rich in maize it tends to counteract the effect of the unsaturated maize oil in producing bacon carcasses of an oily nature.

DRIED BREWERS' YEAST

Dried brewers' yeast results from drying waste yeast from breweries. It contains about 40 per cent of crude protein, practically no fibre and no oil, but about 10 per cent of ash. The ash contains about 5.5 per cent of phosphate but only 0.3 per cent of lime, and if fed in any quantity it is important to include chalk in the diet to restore the lime-phosphate ratio to near unity, otherwise rickets may develop. Dried yeast is particularly rich in the vitamin B complex, and 2 to 3 per cent included in poultry mashes safeguards the supply of vitamin B₁ and riboflavin. It is deficient in vitamin B₁₂. The proteins of dried yeast have a high biological value being comparable to the proteins in white fish meal, on a pound for pound basis, for feeding to pigs.

ANIMAL FEEDINGSTUFFS

WHITE FISH MEAL

White fish meal must be made solely from the flesh and bones of white fish such as cod, haddock, plaice, ling, sole, etc., which are low in oil content. The gutting is carried out at sea, the entrails being thrown overboard, and the livers are also removed and packed separately. On arrival at port the fish are filleted for the fish trade and the heads and bones with a good proportion of adhering flesh, amounting to about 40 per cent of the whole, are taken to the fishmeal factory. Here the offal passes through vacuum sterilizers, initial cookers, drying tubes, grinders and riddles, to the bagging and weighing machines. Its original moisture content of 85 per cent is reduced to about 10 per cent, but the drying is effected at a low temperature to avoid damage to the nutritive value of the proteins. By regulation white fish meal must not contain more than 6 per cent of oil and not more than 4 per cent of common salt, and should have a light-yellowish colour with a slight fishy smell. The proteins are 95 per cent digestible by pigs.

OILY FISH MEAL OR HERRING MEAL

As the term implies, it is made from oily fish such as herring, pilchards, sprats, and menhaden. The fish are partially cooked and then subjected to hydraulic pressure to squeeze out as much edible oil as possible. The residue is then treated in much the same way as in making white fish meal. Herring meal generally contains 8 to 10 per cent of oil and is usually richer in protein than

white fish meal. The amount of herring meal made from salted herring negligible. The fish meal used in commercially-produced compound feeding stuffs is largely oily fishmeal. It is a valuable protein-rich concentrate.

Fish meal is an ideal supplement for feeding with cereal grains. It contains between 62 and 72 per cent of crude protein, and moreover, being an animal protein it contains all the essential amino-acids, these being present in fish proteins in roughly the same proportions as in milk proteins. Fish meal containing the bones of the fish, is also a rich source of lime and phosphorus thus rectifying the deficiency of these minerals in cereal grains.

Since the supply of fish meal is inadequate to meet the demand for it, it is fed mainly to young animals. It is wasteful to feed fish meal to baconers after they attain 100 lb live-weight. It is also advisable to discontinue the feeding of fish meal to pork pigs for at least 3 weeks before slaughter. Fish meal is not a rich source of vitamins A or D but supplies adequate amounts of vitamin B₁₂ and some vitamin E.

MEAT AND BONE MEAL

Pure meat meal is made from the material trimmed off the carcasses shortly after slaughter and is cooked in steam-jacketed melters until the moisture content has been reduced to 5 to 8 per cent, the mass being stirred continually. The surplus fat is then drained off. The residual material is then pressed in an expeller to remove a further substantial portion of fat. Pure meat meal contains over 70 per cent of crude protein and only 3 to 4 per cent of ash. The amount manufactured is small owing to the difficulty of rendering the fat without the addition of bone.

There are two types of meat meals known as commercial feeding meat meal and feeding meat and bone meal. The former is guaranteed to contain not less than 55 per cent of protein and not more than 4 per cent of salt. It contains about 20 per cent of minerals. Meat and bone meal is guaranteed to contain not less than 40 per cent of protein and not more than 4 per cent of salt. It contains about 24 per cent of minerals.

The meat meals are used in much the same manner as white fish meal though they are generally regarded as being slightly inferior in feeding value.

WHALE MEAT MEAL

The outstanding feature of pure whale meat meal is its extreme richness in crude protein, which may amount to as much as 88 per cent. This is due to the modern method of removing the muscular tissue along the backbone of the whale unmixed with bone, the ash content of the meal being as low as 2 per cent. Commercial samples of whale meat meal may, however, have bone or minerals added to them. Thus, whale meat flakes or whale meat meal with 60 per cent of protein but with 16 per cent of ash are available, the fat also amounting to between 12 and 16 per cent.

BLOOD MEAL

The blood coagulum is first pressed to remove as much of the serum as possible and then dried in steam-jacketed cylinders, *in vacuo*, until the moisture content is reduced to about 5 per cent. The temperature of drying has a distinct bearing on the nutritive value of blood meal. It contains about 80 per cent of protein, and the amount fed to pigs should not exceed 5 per cent of the total ration.

Nutrition of the Ruminant

GENERAL PRINCIPLES OF COMPUTING FOOD ALLOWANCES

It is convenient to regard the ration of an animal as consisting of two parts called the maintenance ration and the production ration, respectively. The former represents the food required to maintain the body's vital functions such as breathing and blood circulation, provide warmth to maintain body temperature and enable the animal to walk about and pick and chew its food, etc. The food used for this purpose is designated the maintenance food allowance, while it prevents loss in weight, it does not allow for any productive processes such as growth or milk production. The scientist defines a maintenance ration as a food allowance that supplies the amount of starch equivalent and digestible protein needed to maintain a non-lactating animal with neither gain nor loss of body fat or protein. Technically it means the animal is in carbon and nitrogen equilibrium. In normal circumstances the bulk of the maintenance requirements is provided for by feeding coarse fodders such as hay, straw, roots, kale, silage and perhaps sugar beet pulp, whereas concentrates are fed for production.

The maintenance requirement is continually changing as the animal grows though it is not directly proportional to the live weight.

The amount of the production ration is independent of the animal's size but varies according to the results which the feeder desires to produce. In a fattening animal liveweight increase per day is by no means the same thing as so much fat stored per day. As an animal gets older and especially as it gets fatter its liveweight increase contains less water and more fat. The portion of the increase that consists of water does not require any starch equivalent for its production; but every 1 lb of fat in the increase requires 4 lb of starch equivalent. It follows, therefore, that the amount of starch equivalent required per lb of live-weight gain is low in the young lean animal but increases continuously in the full-grown fat animal. For the same reason it is desirable to know the percentages of butterfat in the milk, in order to determine the starch equivalent that must be added to the maintenance ration to produce 1 gal.

The necessary starch equivalent and digestible protein must be included in the bulk which an animal can eat. For low production there is no problem since the diet can include considerable amounts of bulky fodder. With high-producing animals the feeder has to rely much more on concentrates and on limiting the amount of bulky food. The quality of the roughage fed is also an important factor.

To work out a suitable ration it is therefore necessary to know:

- (1) The live weight of the animal.
- (2) The liveweight gain desired or the gallons of milk to be produced.
- (3) The appetite or capacity for food consumption of the animal, expressed in lb of dry matter per day.

Other considerations to be taken into account are palatability, succulency, likelihood of digestive upsets or scouring, and whether the food is likely to taint the milk.

The stockfeeder should realise that the so-called feeding standards serve primarily as a guide to the computation of rations and are not meant to be statements of the exact requirements of the animals. This would anyway be impracticable since feedingstuffs vary in composition and the influence of individuality and management must cause considerable variation. Standards generally contain margins of safety above the actual requirements and are designed to cover all cases. This margin is desirable since the standards were determined with stall-fed animals under good conditions of management which it would be difficult to attain in ordinary farm practice, particularly if the animals are nervous and restless. It is preferable, therefore, to use the term "food allowances" rather than "feeding standards", and it must be understood that the final criterion of the adequacy of a ration must be the response of the animal and this the stockfeeder himself must judge and adjust the ration accordingly.

RATIONING FOR BEEF PRODUCTION

When discussing food allowances for beef production it is essential to distinguish between the requirements of cattle reared with a view to sale as mature animals and those intended for baby beef. The essential feature of store raising is the maximum use of cheap roughages or silage during the winter feeding, so that the cattle make the greater part of their liveweight increase when grazing during the summer, this system being economical in the use of concentrates. A large proportion of young stock are reared in this way and grow slowly to attain a live weight of 8 to 9 cwt when about two and a half years of age. These stores are then given an intensive fattening period of 3 to 4 months to put on 2 or 2.5 lb liveweight increase per day, so they are ready to be slaughtered at 10 to 11 cwt.

When calves are reared for baby beef there is no store period, the animal being in a fresh condition throughout. Baby beef production entails the liberal use of concentrates, so as to reduce bulk. The calves may gain at an average rate of nearly 2 lb live weight per day from birth to slaughter and be ready for the butcher at about 18 to 20 months of age when they weigh 9-10 cwt.

MATURE BEEF PRODUCTION

WINTER RATIONING

Our knowledge of the food requirements for mature beef production is based on the balance trials that Kellner carried out in the respiration chamber, and also on the "comparative slaughter" work of Lawes and Gilbert at Rothamsted, by Professor Wood at Cambridge, and of Armsby and others in America. These allowances have now successfully withstood the test of time but it will be interesting to enquire how they fit in with standards used in other countries, and whether recent experimental work suggests the need for any modifications.

To determine the maintenance requirement of cattle, Kellner used eight mature store bullocks. He calculated his results in terms of the standard 9 cwt or 1,000 lb bullock and stated its maintenance requirement to be 5.2 lb of starch equivalent which had to include 0.5 lb of pure digestible protein to prevent breakdown of body protein. He found the maintenance requirement

individuals to vary significantly and also that fat 9 cwt steers had a higher requirement than thin cattle of the same weight. Kellner also realized that cattle are not fattened in respiration chambers, where their movement is restricted, but in yards or sheds, where the muscular energy expended in pursuing their food, etc., is considerably higher. He, therefore, gave the practical maintenance requirement of the 1,000 lb steer as 6 lb of starch equivalent including 0.6 to 0.7 lb of protein equivalent.

Many authorities have since carried out controlled feeding trials on penned bullocks in animal calorimeters, to determine their maintenance requirement, and the general average has been found to lie somewhere in the neighbourhood of 5.6 lb of starch equivalent per day. Authorities in the U.S.A. advocate a higher standard of 7 lb starch equivalent for the maintenance of the 1,000 lb steer.

Having determined experimentally the requirement of the 9 cwt steer, Kellner then proceeded to calculate the maintenance requirement of cattle of other live weights. Most authorities agree that the maintenance requirement of cattle of 5 cwt and upwards is proportional to two-thirds power of the live weight, though American scientists have recently suggested three-quarters power of the live weight to be more accurate; a refinement of little practical significance. The protein equivalent requirements were considered to be directly proportional to live weight so that a 10 cwt bullock required twice the amount necessary for the 5 cwt beast.

The maintenance requirement, however, varies slightly with the plane on which the animal is being fed. It is rather higher with a heavily fed animal than with a store beast (see pages 51 and 64). The appetite and requirements of starch equivalent for animals growing at normal rates are shown in the following table:

TABLE 1 *Appetite and Starch Equivalent required for Maintenance*

Live weight of bullock* (cwt)	Appetite dry matter (lb per day)	Maintenance S.E. (lb per day)
5	14.5	4
6	17	4.5
7	19	5
8	20.5	5.5
9	22	6
10	23.5	6.5
11	25	7
12	26.5	7.5
13	28	7.75
14	29.5	8.25

No data are given for the maintenance requirements of cattle below 5 cwt live weight, since the law that the starch equivalent for maintenance is proportional to the two-thirds power of the live weight does not apply to such young stock. It is certain that the requirements are higher than would be predicted from the application of this law, but how much higher has not as yet been determined by scientific experiment. Until further information on this point has been obtained, therefore, the feeding of calves and very young stock must continue to depend on the feeder's skill and experience rather than on the use of scientific feeding standards.

APPETITE

The figures giving the appetites of bullocks of different live weights are based on the recorded food consumption of animals under experiment, as published in the literature. They were obtained under conditions of winter feed. Bulk is expressed in terms of dry matter, so as to allow for differences in moisture content between roots, silage and concentrates. The dry matter percentages in feeds is given in column 1 of the Tables. Individuals will vary considerably in their capacity to eat and the palatability of the foods is an important factor. Bulk should really be a measure of the "fill-belly" capacity of the food which is in turn influenced by the amount of water the food absorbs and the consequent swelling that takes place in the digestive tract. Dry matter is therefore an inadequate expression of bulk. American nutritionists stress the need for a minimum of 0.7 to 0.8 lb of roughages (air dry basis) per 100 lb live weight, to maintain appetite and to aid mastication and rumination and enable the animal to get the most out of its food. It will be appreciated that the figures for appetite have no absolute significance but are merely guides to assist the stockfeeder. There is a strong tendency for food consumption to decrease towards the end of the fattening period.

PRODUCTION REQUIREMENTS

The amount of starch equivalent and protein equivalent that must be added to the maintenance food to give 1 lb liveweight increase per day depends on the composition of the liveweight gain or the stage of fattening. In the young animal liveweight gain is normally composed largely of protein, minerals and water since the animal is building its framework, but in mature fat cattle liveweight increase means almost pure fat deposition.

To determine the composition of the liveweight increase the method of comparative slaughter was used. A number of calves or yearlings were selected so as to be as nearly alike as possible in age, weight, condition and breeding, etc. They were fed as stores until 8 cwt live weight and then given an intensive fattening period, as already described. At the start of the experiment the animals were weighed on three consecutive mornings and the figures for each animal averaged to get as true a measure of its live weight as possible. An animal representative of the whole bunch was then selected, weighed, slaughtered, dissected and its carcass was analysed. In about 50 days the whole procedure was repeated and another representative animal picked and slaughtered. This continued until the remaining animals had attained 14 cwt live weight or more.

The protein content of the liveweight gain varies inversely with the liveweight, ranging from 0.25 lb in 1 lb gain in the young calf to as little as 0.05 lb in a similar gain in a 10 cwt fat beast. Details of protein contents were as follows:

Protein content at different live weights

Live weight (cwt)	lb protein in 1 lb liveweight gain
1 - 3	0.25-0.20
3 - 5	0.20
5 - 6.5	0.18
6.5- 8	0.16
8 - 9	0.15
9 -10 Store condition	0.15
half fat	0.10
fat	0.05

STARCH EQUIVALENT REQUIRED TO PRODUCE 1 lb LIVELWEIGHT GAIN

To illustrate how the results of comparative slaughter are used to determine production requirements, let us assume that the difference in chemical composition between beasts slaughtered at 600 and 700 lb liveweight respectively, was found to be 18 lb of protein and 40 lb of fat, the remainder being water and minerals. We can calculate the calorific value in 1 lb gain, over this period, as follows:

Calories in protein	$0.18 \times 5.7 \times 454 =$	466
Calories in fat	$0.40 \times 9.5 \times 454 =$	1,725
Total calorific value per lb		<u>2,191C</u>

(5.7 represents KCal in 1 g protein; 9.5 KCal in 1 g fat)

Mellner found (p. 3) that 4 lb of starch equivalent will produce 1 lb of body fat which will contain 4,284 calories. The 2,191 C shown above will, therefore need $(\frac{4}{4284} \times 2191) = 2$ lb starch equivalent approximately. The figures for starch equivalents required in addition to maintenance, per lb liveweight gain, set out in Table 2 (p. 50), were computed from such determinations. The amount required varied from 1.3 in the young calf to 4 lb S.E. in a very fat beast.

PROTEIN EQUIVALENT

The figures given above for the protein content in 1 lb liveweight gain show how this constituent gradually declines from 0.25 in the young calf to as little as 0.05 in the fat beast, and it would be reasonable to assume the supply of protein in the food could be correspondingly reduced. It will be seen from Table 2, however, that in practice the total protein required for maintenance and liveweight gain is 1.5 lb for the 8 cwt beast *and that it is maintained at this figure for the remainder of the fattening period*. It will also be evident that the figures do not express protein requirements as this would make no allowance for wastage in converting food protein into flesh.

It is satisfactory to note that although the late Professor T. B. Wood gave the requirement of the 8 cwt bullock as 1.5 lb of protein equivalent per day as early as 1924, a committee of American experts in a recent review of the protein requirements of cattle found the minimum levels they considered adequate agreed closely with Wood's standards.

The protein supply in the food is not reduced as fattening progresses for the following reasons. Oilcakes are fed not only to make up the deficiencies in protein of home-grown foods but also because they supply a large amount of starch equivalent in a small bulk. The factor of bulk is most important since the animals' appetite tends to decrease as fattening proceeds, and its rate of gain may not be maintained. Food consumption is also greatly influenced by the palatability of the foods, and concentrates are generally more palatable than home-grown foods. (It is for this reason that American nutritionists recommend an increase from 1.5 lb of digestible protein per day at 800 lb live weight to as much as 1.8 lb at 1,200 lb, an amount that supplies far more protein equivalent than is necessary.)

In the following Table, therefore, which is based upon such trials, while S.E. requirements are stated separately, those for protein equivalent are combined with maintenance requirements:

TABLE 2 *Nutrient requirements per day*

Live weight (cwt)	Starch equivalent required in addition to maintenance lb per lb liveweight gain	Total Protein Equivalent required for maintenance and liveweight gain lb
1-3	1.1-1.5	} 1.25
3-5	1.5-1.8	
5-6.5	1.8-2.0	
6.5-7.5	2.0-2.25	
7.5-8.5 Store	2.25	} 1.5
Fresh	2.5	
9-10 Store	2.5	
Fresh	2.75	
Half fat fat	3.0 4.0	

An allowance of 1.5 lb of total protein equivalent per day should permit a liveweight gain in a 9 cwt bullock of 2 to 2.5 lb. If the liveweight gain aimed at is only 1 lb per day, as in store feeding, it will not be necessary to feed so much protein. The maintenance requirement of a 9 cwt steer is 0.6 to 0.7 lb of protein equivalent per day. If we add about 0.3 lb of protein or twice the amount in the tissue, for 1 lb liveweight increase the total protein requirement becomes about 1 lb of protein equivalent per day.

During the fattening period most feeders aim at a liveweight increase around 2 lb per day. While it is true that some animals will gain 2.5 lb or even 3 lb per day, particularly if in poor condition at the start, their rate of gain will tend to fall as fattening progresses. Other cattle, because of poor appetite or some similar cause will only put on 1.75 lb per day. Some cattle are genetically incapable because of poor breeding of gaining more than 1.5 lb a day. By aiming at 2 lb liveweight increase per day the feeder is also able to include a fair amount of roughage in the diet.

We must, however, repeat that the food allowances recommended are not true standards and have been designed mainly as a guide. The experienced stockman will make the necessary adjustments to cover individuality and variations in food composition. This is also necessary since individuals may show considerable variation in maintenance requirement. All animals have not the same efficiency of food conversion and if the animal is nervous or is beaten at the trough owing to overcrowding, then the calculated ration will probably be on the small side. The standards were worked out under conditions of good management.

BABY BEEF PRODUCTION

Young cattle intended for baby beef are fed intensively from birth so as to reach the meat market at from 18 to 20 months old, when they scale from 7 to 10 cwt live weight. They are usually reared out of doors under their own dams or multiple-suckled, or they may be bucket-fed on milk and milk substitutes. Since it is essential to maintain constant growth and fattening with no store period, the feeding of straw or poor quality roughage is ruled out, only the best hay or grass silage with roots and concentrates being fed to baby beef in this respect competing with the dairy herd.

Baby beef production is more an art than a science. Very little is known about the maintenance requirement of fat calves since most of the work in this field was carried out with mature stores and the figures do not legitimately apply. Again the comparative slaughter work to determine the composition of the liveweight increase in calves is quite inadequate to serve as a basis for establishing the production requirements of fast-growing animals. Only tentative recommendations for food allowances can be made, though it is hoped these may give some guidance to the feeder when checking the adequacy of the diet.

The requirement for maintenance varies with the plane of nutrition on which an animal is kept. A baby beef animal being in good nutritive condition or on a high plane of nutrition, must have a higher maintenance requirement than a store bullock of the same live weight, which will be on a low plane of nutrition. To draw up a tentative table of feeding standards for baby beef we could add an extra $\frac{1}{4}$ lb of starch equivalent to the maintenance figures that Kellner obtained with store cattle.

It will also be necessary to add 0.25 lb of starch equivalent to the figures given per 1 lb liveweight increase, in Table 2 (p. 50). For example, it will be noted that between 12 and 18 months, or between 5 and $6\frac{1}{2}$ cwt, the results of comparative slaughter show that to produce 1 lb liveweight gain it is necessary to add to the maintenance diet 1.8 to 2 lb of starch equivalent. For baby beef production the animal must be regarded as being in fresh condition and will therefore require $(1.8 + 0.25)$ 2.05 lb starch equivalent per lb gain. The figures given in the following table were computed on this basis:

TABLE 3 *Tentative standards for baby beef production to put on 2 lb L.W.I. per day*

(See footnote to Table 1. p. 47.)

Body weight	Appetite dry matter	Maintenance ration per day S.E.	Production ration for 2 lb L.W.I. per day	Total lb starch equivalent per day	Total protein equivalent per day
	lb	lb	lb	lb S.E.	lb
5 cwt	14.5	4.25	4.10	8.35	1.25
6 cwt	17	4.75	4.50	9.25	1.25
7 cwt	19	5.25	4.75	10.00	1.50
8 cwt	20.5	5.75	5.00	10.75	1.50

The total starch equivalent allowances are rather lower than those advocated by American authorities as based on the results of feeding trials with fattening yearling cattle.

COMPUTING RATIONS FOR FATTENING MATURE CATTLE

The following examples show how Tables 1 and 2 (pp. 47 and 50) should be used for calculating the rations of beef cattle and illustrate the principles involved:

Calculating a ration for 2-year-old stores of about 8 cwt liveweight to fatten at the rate of about 2 lb per day and be ready for the butcher in 4-5 months at 10-10.5 cwt live weight.

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References to the table of allowances shows that store cattle of about 8 cwt live weight require 5.5 lb of starch equivalent per day for maintenance and in addition, $2 \times 2.25 = 4.5$ lb of starch equivalent for the 2 lb of liveweight increase. The total requirements therefore are 10 lb of starch equivalent including 1.5 lb of protein equivalent and the bulk of dry matter in the daily ration must be in the neighbourhood of 20.5 lb.

ROOTS, HAY AND OAT STRAW

Suppose the maintenance foods available on the farm are swedes, a little hay and oat straw. It is seen from the Tables of Composition at the end of the Bulletin that 100 lb swedes contain 11.5 lb of dry matter, 7.3 lb of starch equivalent and 0.7 lb of protein equivalent; 100 lb good hay, 85 lb of dry matter, 36 lb of starch equivalent and 4.1 lb of protein equivalent; 100 lb of oat straw, 86 lb dry matter, 20 lb starch equivalent and 0.9 lb of protein equivalent.

Let us assume the farmer can spare 50 lb of swedes and 7 lb of hay per head per day and, since a suitable daily allowance of roughage is about 14 lb per head, the oat straw is allowed at the rate of 7 lb per day. The total nutrients provided by the bulky foods may then be set out as follows:

	<i>Dry matter</i> <i>lb per day</i>	<i>Starch</i> <i>equivalent</i> <i>lb per day</i>	<i>Protein</i> <i>equivalent</i> <i>lb per day</i>
50 lb swedes . . .	5.7	3.6	0.35
7 lb hay . . .	6.0	2.5	0.29
7 lb oat straw . . .	6.0	1.4	0.06
	17.7	7.5	0.70

To bring up the ration to the total requirements the concentrate supplement must supply in about 2.8 lb of dry matter, 2.5 lb of starch equivalent including 0.8 lb of protein equivalent. Since the starch equivalent of soya-bean meal is 64 and that of crushed oats 60, we could feed the following mixtures:

	<i>Dry</i> <i>matter</i> <i>lb</i>	<i>Starch</i> <i>equivalent</i> <i>lb</i>	<i>Protein</i> <i>equivalent</i> <i>lb</i>
2 lb soya-bean meal . . .	1.8	1.28	0.76
2 lb crushed oats . . .	1.7	1.20	0.15
	3.5	2.48	0.91
add maintenance ration	17.7	7.5	0.7
	21.2	9.98	1.61
Total . . .	21.2	9.98	1.61

The ration made up as described would be slightly on the high side in respect of content of dry matter (21.2 lb compared with 20.5 lb given in Table 3) but part of the oat straw would be given long in the rack so that cattle could adjust consumption to appetite by consuming slightly less straw.

On farms where the cultivation of sugar beet has largely replaced the growing of swedes, dried sugar beet pulp will tend to replace roots in the ration of fattening cattle. It will be recalled that 1 lb of dried beet pulp will replace 8 lb of swedes, and that it should be well soaked in twice its weight of water before feeding. Sugar beet tops would be equally suitable to replace

for the whole of the swedes on a weight for weight basis. If no hay can be had then silage or marrowstem kale will prove satisfactory substitutes.

ARABLE SILAGE AND HAY

Suppose the maintenance foods available on the farm are oat and vetch silage, and a little meadow hay, and that ground-nut cake can be purchased at an oilcake. Let us also assume these feedingstuffs to have the following composition per 100 lb: Oat and vetch silage 25 lb of dry matter, 11.7 lb of starch equivalent and 2 lb of digestible crude protein; medium hay 85 lb of dry matter, 32 lb of starch equivalent and 3.6 lb of protein equivalent; ground-nut cake 90 lb dry matter, 70 lb of starch equivalent and 39 lb of protein equivalent. The farmer considers that the available supplies will permit the feeding throughout the fattening period of 30 lb of silage per head per day, with about 5 lb of hay. These together represent, therefore, the feeding of about 12 lb of air-dry maintenance fodder. To this may be added 10 lb of decorticated ground-nut cake to raise the figure for the protein equivalent to the neighbourhood of 1.5 lb per day. The nutrients supplied so far may be set out as follows (lb per day):

	<i>Dry matter</i>	<i>Starch equivalent</i>	<i>Protein equivalent</i>
30 lb oat and vetch silage	7.5	3.5	0.60*
5 lb of good hay . . .	4.2	1.6	0.18
1 lb ground-nut cake . .	0.9	0.7	0.39
	12.6	5.8	1.17

further 4.2 lb of starch equivalent must be provided to raise the allowance to the full requirement of 10 lb but the protein equivalent necessary to obtain a total of 1.5 lb is only 0.3 lb. A cereal grain should supply the necessary balance of extra nutrients and 7 lb of crushed oats provide 4.2 lb of starch equivalent and 0.53 lb of protein equivalent. The ration then comes (lb per day):

	<i>Dry matter</i>	<i>Starch equivalent</i>	<i>Protein equivalent</i>
Allowance as above . . .	12.6	5.8	1.17
7 lb crushed oats . . .	6.1	4.2	0.53
	18.7	10.0	1.7

The ration made up as described would be slightly on the low side in respect of content of dry matter (18.7 lb compared with 20 lb) but rather generous in protein and the farmer may wish to substitute a little oat straw and long in the rack so that the cattle could adjust consumption to appetite and reduce the hay to 4 lb. A farmer feeding silage would also probably take the precaution of having a sample analysed by the National Agricultural Advisory Service since this feedingstuff shows considerable variation in moisture content even in different parts of the silo, and its protein content is also variable. On farms growing sugar beet, dried sugar beet pulp can be fed on a pound for pound basis to replace a part of the oats.

* Digestible Crude Protein figures are substituted in the case of silage.

At this level of feeding our store or lean animal will soon be in a forward or fresh condition. Thus after about 3 weeks it will be advisable to allow 2.5 lb of starch equivalent per lb liveweight gain instead of 2.25 lb hitherto. For 2 lb liveweight increase the requirement becomes therefore 5 lb starch equivalent or an increase of 0.5 lb. This can conveniently be supplied by feeding another pound of crushed oats or sugar beet pulp or a mixture of equal parts of crushed oats and crushed barley, any of which would supply 0.6 lb starch equivalent. It will be noted that the requirement for protein equivalent does not increase but remains stationary at 1.5 throughout the fattening period. Thus any further additions to the ration to meet increased maintenance or production requirements, should be carbohydrate-rich foods.

As the animal increases in live weight, it will be necessary from time to time to adjust the size of its ration if the liveweight gain of 2 lb per day is to be maintained. By the end of two months the bullocks should have reached an average live weight of about 9 cwt. The daily maintenance requirement during this period will have risen from 5.5 to 6 lb of starch equivalent per head and the production requirement from 2.5 to 2.75 lb per lb liveweight gain. The total starch equivalent needed to maintain the rate of gain at this level of 2 lb per day at this stage is, therefore, $6 + (2 \times 2.75) = 11.5$ lb. On this ration the bullocks will fatten steadily to a live weight of about 10 cwt and should by then be in half-fat condition. At 10 cwt the maintenance requirement will have increased further to 6.5 lb of starch equivalent, and since the liveweight increase is becoming progressively richer in fat content it will not be necessary to feed 3 lb of starch equivalent per lb gain or a total of 12.5 lb. It will be apparent therefore that an increase each month of 0.5 lb starch equivalent per day is necessary to maintain a daily liveweight gain of 2 lb.

For further information the reader should consult the Ministry's Bulletin 178*.

WINTER MILK PRODUCTION

The same principles are applicable to the rationing of dairy cows for milk production as to the feeding of bullocks for liveweight increase. In computing food allowances for cows it is assumed that the sole object is milk production, no allowance being made for growth.

FEEDING STANDARDS

Data respecting the maintenance and production requirements are given in the accompanying table. In the first part are recorded the maintenance requirements in terms of starch equivalent and protein equivalent in relation to live weight. The average live weights of the different breeds, together with estimated requirements, are also given. The production requirements per gal of milk naturally depend on the richness of the milk in respect of fat and in the second part of the table are shown the requirements of starch equivalent and protein equivalent per gal of milk of varying fat content. The average fat content in the milk of the different dairy breeds is given as a guide to their respective requirements.

* *Beef Production*, price 5s. (by post 5s. 5d.) obtainable from H.M. Stationery Office or through any bookseller.

TABLE 4 *Requirements for Production Milk*

(1) Maintenance (per day) according to live weight and breed.

Live weight	S.E.	P.E.		Live weight	S.E.	P.E.
<i>cwt</i>	<i>lb</i>	<i>lb</i>		<i>cwt</i>	<i>lb</i>	<i>lb</i>
6	4.5	0.50	Dexter . .	5.8	4.4	0.39
7	5	0.55	Jersey . .	7.1	5.1	0.48
8	5.5	0.60	Kerry . .	7.6	5.3	0.51
9	6	0.65	Guernsey .	8.5	5.8	0.6
10	6.5	0.70	Ayrshire .	9	6.0	0.65
11	7	0.75	Welsh Black .			
12	7.5	0.80	Devon . .	10	6.5	0.7
13	7.75	0.85	Red Poll . .			
			Dairy Shorthorn	11	7.0	0.75
			British Friesian.	11.5	7.3	0.78
			Lincoln Red .	13	7.75	0.85
			S. Devon . .			

(2) Production (per gal of milk).

	Per cent fat in milk	S.E. lb	P.E. lb
	3.5-3.8	2.5	0.5
	3.9-4.0	2.6	0.55
	4.1-4.3	2.75	0.6
	4.4-4.6	2.9	0.63
	4.7-4.9	3.0	0.65
	5.0-5.1	3.1	0.70
	5.2-5.3	3.25	0.75

Classification of breeds by fat percentage

Average per cent fat in milk

British Friesian . .	3.5 per cent
Lincoln Red . .	3.6 per cent
Red Poll . .	3.6 per cent
Dairy Shorthorn . .	3.6 per cent
South Devon . .	4.3 per cent
Ayrshire . .	3.8 per cent
Dexter . .	4.2 per cent
Devon . .	3.9 per cent
Kerry . .	4.0 per cent
Guernsey . .	4.6 per cent
Jersey . .	5.1 per cent

Many authorities simplify the above table and classify average requirements for production as follows:

Breed	Starch equivalent	Protein equivalent
	<i>lb</i>	<i>lb</i>
Jersey	3.0	0.7-0.75
Guernsey		
S. Devon		
All other breeds . .	2.5	0.5-0.55

MAINTENANCE

The maintenance requirements of dairy cows are the same as for steers of the same weight. This seems to ignore the requirements for the growth of the foetus, placenta and mammary glands, since most lactating cows are in calf. It has been shown, however, that the daily requirement of food nutrients for this purpose is quite small except during the last two months of pregnancy when the cow will ordinarily have dried off and will moreover, be "steamed up" in preparation for the next lactation.

PRODUCTION

Starch Equivalent

The requirements per gallon of milk are based on calorimetric and respiration chamber studies as well as on the results of large-scale feeding trials. To produce a gallon of average milk (3.5 per cent fat) it is necessary to add to the maintenance ration 2.5 lb of starch equivalent which must include at least 0.5 lb of protein equivalent. With Jersey cows, giving a high quality milk containing 5.1 per cent butterfat, the requirement per gallon rises to 3.25 lb of starch equivalent, including at least 0.7 lb of protein equivalent. It will be seen from Table 4 (p. 55) that the requirements of other breeds fall in between these values. A gallon of average milk, produced by feeding 2.5 lb of starch equivalent contains about 3,400 Calories. One lb of starch equivalent in milk production, therefore, gives rise to the storage of 1,360 Calories in milk protein, fat and lactose. The starch equivalent required to produce a gallon of milk of any given composition is obtained by dividing its calorific value by 1,360. In fattening, 1 lb of starch equivalent only produces 1,071 Calories. It may be noted in passing that food is much more efficiently used in milk than in beef production. The percentage of fat is the main factor that determines the amount of starch equivalent and protein equivalent required per gallon.

A factor with a bearing on these requirements, however, is the gallonage of milk being produced by the cow at the time. There is evidence that the nutritive requirements per gallon rise with increasing yields, but the extent to which the standard requirements differ with each successive gallon of output is not yet known. The rise in requirements attributable to additional quantity may be partly offset by a falling off in the compositional quality of the milk with the higher yields, for the contents of butter fat and solids-not-fat tend to be minimal around the period of peak production.

The British standard of 2.5 lb S.E. per gal of 3.6 per cent fat is slightly lower than that adopted in Denmark where 2.8 lb of S.E. per gal of 4 per cent fat milk is allowed. Nevertheless the British standard has stood the test of many years' experience and in the writer's opinion there is no justification for raising it at the present — save, perhaps, during the flush period of the lactation. Since Danish milk averages 4.27 per cent fat it is likely that the relative efficiency of conversion of food nutrients into milk constituents tends to be less favourable than in the production of milk with 3.6 per cent fat, thus necessitating a higher production allowance.

Protein Equivalent

In former editions of this Bulletin an allowance of 0.6 lb of protein equivalent per gallon has been recommended, partly on the grounds that it

provided a margin of safety in the event of the basal diet of hay and silage being lower in protein equivalent than the user estimated. Many authorities consider this allowance over generous and point to the experimental evidence that 0.5 lb is sufficient. This amounts to a reduction in the protein equivalent of the production mixture from 18 to 15 per cent, the S.E. being maintained at 12 per cent and the quantity fed being standardized at 3.5 lb per gal.

Danish standards, which are based largely on feeding trials conducted for many years by the cow-testing associations, are again a little more generous than British standards being designed to meet the requirements of more intensive milk production. For a gallon of milk of 4 per cent fat content the Danish allowance is 0.6 lb of digestible pure protein in contrast with 0.5 lb protein equivalent given in the table. It is interesting to note that recent experiments carried out in Norway confirm that whereas 0.6 lb of digestible crude protein per gallon of 4 per cent fat milk probably represents the optimum amount, with a high quality protein such as herring meal the allowance per gallon can be reduced to 0.43 lb with only a slight fall in milk production and in the protein content of the milk, the cows remaining in good condition. The quality of the protein is really the deciding factor in determining the allowance of protein equivalent per gallon.

Probably the best advice that can be given at present is that for moderate producers the quantity of protein equivalent per gallon of milk containing 5 per cent fat can be safely reduced to 0.5 lb. For high yielders a little extra protein may stimulate milk production and the extra oilcake will improve the palatability of the milk mixture.

The most critical period in the lactation is the first 6–8 weeks after calving. In practice it is usual to feed extra concentrates to meet the requirement for about half a gallon more milk than the cow is actually giving during this period. It must be emphasized that the feeding of the heavy yielder should be viewed by the stockman as an individual problem, and the normal allowance of so many pounds of balanced food per gallon must be accepted only as a guide (see p. 61, on rationing of high yielders).

COMPOUNDING RATIONS

The figures in the appetite column of Table 1 on page 47, refer to growing and fattening bullocks. Dairy cows are capable of consuming larger amounts of dry matter per day than bullocks of equal live weight. The amount of food that a dairy cow may be expected to consume is usually found to lie around 2 and 3 lb of dry matter per day per 100 lb of live weight. Thus a cow of 10–11 cwt is capable of consuming on an average 30–33 lb of dry matter per day which is approximately equal to 34–37 lb of air-dry food. Similarly, a cow of 13 cwt should consume 39 lb of dry matter equal to 44 lb of air-dry food per day. But bulkiness varies with the quality of the roughage and the amount consumed is inversely proportional to the indigestible matter fed.

THE MAINTENANCE RATION

The maintenance ration is supplied by the bulky foods such as hay, straw, roots, kale and silage. The scaling of the maintenance requirements in relation to live weight is shown in the table of food requirements (p. 47). The following are a few of the many possible rations of bulky foods that would supply these requirements for a cow of 10–12 cwt.

- (1) 18 to 20 lb of good meadow hay.
- (2) 12 lb of good meadow hay and 40 lb of mangolds.
- (3) 12 lb of good hay and $4\frac{1}{2}$ lb of dried sugar-beet pulp.
- (4) 10 lb of good meadow hay, 4 lb of oat straw and 20 lb of oat-and-vetch silage.
- (5) 14 lb of good oat straw and 30 lb of oat-and-vetch silage.

For the maintenance of a 800 lb Jersey cow suitable rations would as follows:

- (1) 14 lb of good meadow hay.
- (2) 8 lb of good meadow hay and 35 lb of mangolds.

The better the type of coarse fodder fed the more protein equivalent will contain so that less high-protein cake will be necessary in the production ration to meet the requirements. Most farmers try to supply in home-grown fodders more than a maintenance diet; by producing super hay or good grass silage it is possible to design rations from the bulky fodders that will provide the necessary starch equivalent and protein equivalent for maintenance and the first two or even three gallons of milk. Yields of over 1,000 gal have been claimed from the self-feeding of silage, without any concentrates, the diet during the four winter months consisting solely of silage and the average consumption amounting to 130 lb per head daily. Norwegian workers, however, consider it doubtful whether any advantage is gained by replacing hay completely with silage and suggest that optimum daily amounts to feed are around 40 to 50 lb of silage with 10 to 20 lb of hay. In general, harvesting fodder crops at an early stage of growth makes it possible to supply the necessary nutrients for maintenance and some production without exceeding the intake capacity of the cow. Examples of rations designed to supply the requirements for maintenance and the first gallon for dairy cows of 10-11 cwt live weight are as follows:

- (1) 15 lb of good hay plus 40 lb of kale or cabbage.
- (2) 7 lb of lucerne hay plus 10 lb of good hay plus 50 lb mangolds.
- (3) 18 lb of good hay plus 40 lb of mangold *or* 4.5 lb of dried sugar beet pulp *or* 15 lb of brewers' wet grains *or* 24 lb of molassed grass silage *or* 4.5 lb of dried young grass *or* 3 lb of barley meal plus 0.5 lb of linseed cake.

For maintenance plus 2 gallons:

15 lb of good hay plus 40 lb of high-protein silage plus 4 to 6 lb of crushed oats; the mixture supplying around 24 lb of dry matter so that a further 7 lb of concentrates can be consumed in the production ration.

THE PRODUCTION RATION

The conventional method of computing winter rations is first to decide on a suitable common diet of bulky foods for all the cows in the herd. This should provide the nutrients for maintenance plus the first half gallon of milk. This basal diet is then supplemented by an allowance of balanced concentrates to be fed on the basis of milk yield. A balanced milk-production mixture should contain 72 lb of starch equivalent and 15 lb of protein equivalent per 100 lb so that 3.5 lb will provide 2.5 lb of starch equivalent and 0.53 lb of protein equivalent, or enough for a gallon of average milk. Cows of the Channel Islands breeds will require 4.5 lb of such a milk-producing mixture per gallon of milk. Table 5 gives examples of suitable mixtures.

TABLE 5. *Milk-producing mixtures*

Mixture	S.E.	P.E.	Mixture	S.E.	P.E.
	<i>lb</i>	<i>lb</i>		<i>lb</i>	<i>lb</i>
100 lb dec. ground-nut cake	73	42	100 lb dec. ground-nut cake	73	42.0
100 lb maize meal	155	15.8	150 lb crushed barley	106	11.4
100 lb crushed barley	71	3	100 lb coarse middlings	56	11.6
100 lb crushed oats	60	8	200 lb maize meal	155	15.8
100 lb of the mixture supplies	32.9	73.8	550 lb of mixture supplies	390	80.8
100 lb of the mixture supplies	71.8	14.76	100 lb of mixture supplies	71	14.7
100 lb (all breeds except Channel Island)	2.51	0.52	3.5 lb of mixture supplies	2.49	0.51
100 lb (Channel Island Breeds)	3.23	0.66	4.5 lb of mixture supplies	3.20	0.66

On many farms it is essential to include a fair proportion of crushed oats in the milk-producing mixture, if the maximum use is to be made of home-grown feedingstuffs. A suitable mixture is given in the following table:

TABLE 6. *Mixture including home-grown feedingstuffs*

Mixture	S.E.	P.E.
	<i>lb</i>	<i>lb</i>
600 lb crushed oats	360	48
100 lb dec. ground-nut cake	73	42
100 lb palm-kernel cake	73	17.5
800 lb of mixture supplies	506	107.5
100 lb of mixture supplies	63.2	13.4
4 lb of mixture supplies	2.53	0.54
5 lb of mixture supplies	3.16	0.67

When oats form a major constituent of the mixture it is not possible to provide the necessary nutrients for a gallon of average milk by feeding 3.5 lb, unless an equal amount of maize is also included. The starch equivalent of oats is 60, that of barley 71 and that of maize 80, so that a mixture of equal parts of oats and maize will replace an equal weight of barley without increasing the dry matter. With moderate yielders the feeding of 4 lb of milk-production mixture per gallon presents no great difficulty. When supplies of meat are available, the coarsely-ground grain can partly replace barley in the mixture without upsetting the balance. Farmers who grow sugar beet also wish to replace some of the crushed oats with an equal weight of dried sugar beet pulp though the amount fed should not exceed 6-8 lb per gallon, and the pulp should be soaked in twice its weight of water before feeding. When using linseed cake or crushed beans as a source of protein the following proportions are suitable:

TABLE 7. *Mixture including linseed cake or crushed beans*

Mixture	S.E.	P.E.	Mixture	S.E.	P.E.
	<i>lb</i>	<i>lb</i>		<i>lb</i>	<i>lb</i>
100 lb of linseed cake .	74	25.3	100 lb of crushed beans .	66	20
100 lb of crushed barley .	71	7.6	400 lb of crushed oats .	240	32
100 lb of crushed oats .	60	8.0	100 lb of linseed cake .	74	25.3
300 lb of mixture supplies	205	40.9	600 lb of mixture supplies	380	77.3
100 lb of mixture supplies	68.3	13.6	100 lb of mixture supplies	63.3	12.9
3.75 lb of mixture supplies	2.56	0.51	4 lb of mixture supplies	2.53	0.54
4.75 lb (Channel Island breeds)	3.25	0.65	5 lb of mixture supplies	3.17	0.65

Certain feedingstuffs are balanced for milk production and should be used at the following rates per gallon of average milk (3.6 per cent fat):

- (1) Palm-kernel cake, use at the rate of 3.5 lb per gal
- (2) Coconut cake, use at the rate of 3.25 lb per gal
- (3) Maize-gluten feed, use at the rate of 3.3 lb per gal
- (4) Wheat-bran, use at the rate of 5.9 lb per gal

Wheat-bran is much too bulky as a milk-producing food for high-yielding dairy cows.

It is also interesting to note that 25 lb of molassed grass silage is able to replace 3.5 lb of high-grade balanced concentrates. The use of dried young grass in milk production has already been mentioned on page 32.

The potentialities of dried young grass in milk production is further demonstrated by the following example: A 5 gal Shorthorn cow of 11 cwt live weight requires a ration supplying $7 + (2.5 \times 5) = 19.5$ lb of starch equivalent including $0.75 + (0.5 \times 5) = 3.25$ lb of protein equivalent. Such a cow should consume about 34 lb per day of baled dried grass. This would supply 20.4 lb of starch equivalent, including at least 4.1 lb of protein equivalent. Her requirements for minerals would be about 4 oz of lime and phosphoric acid, respectively, per day and this would be met since the ration would supply 6 oz lime and 4 oz phosphate. The consumption of 34 lb of high-grade dried grass provides the energy, protein and minerals for maintenance and the production of as much as 5 gal of milk per day. High quality coarse fodders are the key to economic milk production.

USE OF STRAW IN DAIRY RATIONS

Difficulties relating to the problem of bulk are apt to arise when a farmer has to use a *poor* grade of meadow hay or oat straw to supply the maintenance requirement of dairy cattle. For example, a ration composed of 14 lb of good meadow hay, 10 lb of oat straw and 40 lb of high grade molassed grass silage will only provide sufficient nutrients for a 2 gal cow, the bulk consumed being 29 lb of dry matter. For a 4 gal cow marrow-stem kale could be used in conjunction with hay and straw, a ration of 56 lb of kale, 16 lb of good meadow hay and 6 lb of oat straw providing the requirements for maintenance and 2 gal of milk with a bulk of only 27 lb dry matter. The cow can still consume 7 lb of milk-production mixture to meet the requirements for the other 2 gal. There is a tendency to attribute to low quality home-grown feeds a greater replacement value in the ration than they actually have.

Little or no straw can be included in the ration of even 2 gal cows when the accompanying fodders are hay and a bulky medium-value type of silage such as oat-and-vetch silage. There is no difficulty in using oat and vetch silage in conjunction with hay and straw in the feeding of cows giving 1½ gal of milk, and straw should be utilized to the fullest extent in the diet of such low yielders.

RATIONING OF HIGH YIELDERS

High-yielding cows are generally able to consume much more than 30 lb of dry matter per day. It is essential to find out the food capacity of each animal and this will greatly simplify the computing of rations supplying the requisite starch equivalent and protein equivalent. A case may be cited of a Shorthorn cow giving 8½ gal of milk per day and consuming 36 lb of balanced concentrates, 6 lb of dried sugar beet pulp and 6 lb of meadow hay; a total of 42 lb of dry matter or 48 lb of air-dry food. As a rule it is necessary, in order to keep the bulk of the ration within the animal's capacity, to cut down the coarse fodder to a minimum needed to assist mastication, regurgitation and chewing of the cud, and this minimum amount is essential to maintain the fat content of the milk. About 6 lb probably represents the lower limit to which the long coarse fodder can be reduced without endangering the well-being of the cow. This is, of course, well below the amount of nutrients necessary for maintenance. The remainder of the maintenance ration has to be made up with carbohydrate concentrates. The nutrients in 10 lb average hay can be supplied in more concentrated forms in one or other of the following ways:

- (1) 2 lb bran, 2 lb crushed oats and 2 lb of crushed wheat or barley.
- (2) 3 lb middlings and 3 lb crushed oats.
- (3) 2.5 lb of brewers' dried grains and 4 lb oats.

By reducing the bulk of the maintenance ration for high yielders the cow is enabled to utilize as much of its food capacity as possible for the production of milk. Feeding concentrates in three or four meals instead of twice a day appears advantageous. Another device is to use such highly digestible and concentrated foods that less than 3.5 lb per gal will suffice. A concentrate mixture containing 76 per cent of starch equivalent and 17 per cent of protein equivalent can be used at the rate of 3.25 lb per gal of average milk, and a mixture of 1 part of decorticated ground-nut cake and 3 parts of flaked maize would provide these amounts. The best quality hay should be reserved for the high yielders and the animals' likes and dislikes should be studied so as to feed the most palatable foods. Continual observation should be kept on the trend of the milk yield and on the condition of the cow, and the mineral supply* must be adequate to compensate for the amount removed in the milk. The danger of constipation must be avoided by supplying laxative foods.

"STEAMING UP" DAIRY COWS

It is essential that the cow should be brought into good nutritive condition, with her body reserves replenished in preparation for the following lactation, if maximum milk yield is to be obtained. Some 6 to 8 weeks before the cow is due to calve she may be given 3-4 lb of balanced concentrates or palm-

* Feeding mineral mixtures to dairy cows is dealt with on page 20.

kernel cake, in addition to its normal maintenance ration, and this may with advantage be increased gradually until it reaches 8 to 10 lb during the first fortnight. The actual amount fed will be governed by the condition of the cow and by her anticipated milking capacity. This practice also prevents the steep rise in the amount of concentrates fed after calving, which might lead to metabolic disturbances.

Summer Feeding of Cattle

GENERAL PRINCIPLES

It has already been pointed out (p. 28) that the composition and nutritive value of pasture grass is continually changing and is governed largely by its stage of growth or by the system of grassland management. Moreover, the yield per acre is very variable both during the season and between seasons, the predominant factor governing yield being the distribution and amount of rainfall. Yields of dry matter per acre varying from 3,000 lb in a poor droughty season to as much as 8,270 lb in a good season were recorded under a system of monthly-rotational close grazings in eastern counties trials. It will be obvious, therefore, that the principles governing the winter feeding of cattle cannot be applied with nearly the same precision to animals that are grazing in the summer. It is possible, however, to give the stockfeeder some guidance in working out the appropriate supplement to feed and the quantity needed.

The first problem is to assess with any degree of reliability the dry matter consumption of cattle on pasture. The available evidence suggests that when the pasturage is abundant and reasonably dry, the amount of food consumed will not differ materially from that eaten by cattle of the same weight when subsisting on winter feed. It has been estimated that a dairy cow of 10-11 cwt will eat on an average 150 lb of grass daily when the pasture is 4-5 in. high and this amount will contain 30-32 lb dry matter. With longer and more mature herbage food consumption may drop to 20 lb of dry matter. Again, if as a result of grazing the bite available is seriously reduced then food consumption also becomes progressively reduced. Recent determinations of actual consumption by cattle of 10 cwt live weight ranged from 24 to 31 lb daily. This great variation in daily dry matter consumption makes it impossible to be precise when dealing with the supplementary feeding of the lactating cow on pasture. Another very important factor is that response to supplementary feeding is very dependent on the time of calving or stage of lactation. It is most important that high-producing animals should get frequent change of pasture as this helps to maintain appetite and ensure adequate food consumption.

The second obstacle to precision is the assessment of the starch equivalent needed to furnish the energy for walking about and grazing the different types of pasture. In the case of milking cows an allowance must also be made for the energy used in walking to and from the milking shed. This energy was not taken into account by Kellner when he established the standards for

each equivalent required for maintenance, since his figures refer to cattle in stalls or covered yards. The allowance should obviously be related to mass or weight to be moved around, the distance covered in search of food and also to the effort of grazing. A good pasture, having a dense nutrient herbage, involves the animal in a minimum expenditure of extra energy in obtaining its daily ration, but a poor pasture, with thin, sparse herbage implies a considerable expenditure of muscular energy in walking out and selecting suitable areas for grazing so as to satisfy or partly satisfy its appetite.

The scientific evidence on the magnitude of this expenditure of energy on grazing is almost non-existent. The only proposals that have been made are those by the late Professor T. B. Wood who suggested allowances as follows:

<i>Type of pasture</i>	<i>Starch equiv. used up in</i>
	<i>the effort of grazing</i>
	<i>lb per day</i>
Good fattening pasture	1
Average pasture	2
Poor pasture	3

These estimates were based on the performance of cattle on pastures of various types and on the fact that calculations made on this basis gave a reasonable assessment of productivity whether measured in terms of live-weight gain or of milk production.

The third problem is concerned with the starch equivalent and protein equivalent content of the herbage being grazed. For pastures that are continuously grazed but never cropped closely (extensive grazing), it may be assumed that 100 lb of dry matter, up to the early summer (April, May, June) contains 56 lb of starch equivalent, including 12.5 lb of protein equivalent. As the season advances, however, the accumulation of mature coarse growth in the herbage leads to a progressive deterioration so that 100 lb of dry matter during the autumn may only provide 40 lb of starch equivalent including 7 lb of protein equivalent.

At the other end of the scale we have young spring pasturage in which the dry matter has the character of a concentrate, being rich in protein and highly digestible. Such grass will contain per 100 lb of dry matter 70 lb of starch equivalent and about 20 lb of protein equivalent. Under conditions of close grazing, so that the grass never attains a height of more than 3-4 in. at any time, the concentrate nature of the dry matter persists throughout the grazing season.

The modern tendency is towards rotational grazing using the electric fence so that the pasture is uniformly grazed-down after each interval of growth. During May and June, under a monthly system of unchecked growth followed by close grazing, the herbage tends to become more balanced due to the appearance of flowering stems at the "flush" period of growth. It will then contain per 100 lb of dry matter about 66 lb of starch equivalent including 13 lb of protein equivalent.

It is apparent from the above discussion that the feeding value of grass is subject to considerable variation which makes any scientific approach to the problem of supplementary feeding rather empirical. The following examples will illustrate the difficulties enumerated above and the method proposed for dealing with them.

SUMMER BEEF PRODUCTION

(1) FEEDING STORE CATTLE OF ABOUT 6 CWT LIVE WEIGHT
MODERATE PASTURE

Let us assume the grass provides per 100 lb of dry matter, 56 lb of starch equivalent including 12.5 lb of protein equivalent, and that the young cattle use about 1 lb of starch equivalent per head per day in the muscular effort of walking and grazing. For maintenance, 4.5 lb of starch equivalent will be needed and for each lb of liveweight gain it should be sufficient at this time to allow 2 lb of starch equivalent. For store cattle of 6 cwt to gain 1 lb per day the pasture must therefore supply $4.5 + 1 + 2 = 7.5$ lb of starch equivalent including 1.25 lb of protein equivalent in a bulk of around 17 lb of dry matter.

Actually, grass of the composition mentioned above will supply $\frac{(17 \times 56)}{100} = 9.5$ lb of starch equivalent including 2.1 lb of protein equivalent. Liveweight gain at first should therefore be at the rate of 2 lb per day without supplementary feeding.

When, after 2 months grazing, the cattle weigh 7 cwt the maintenance requirement will have risen to 5 lb starch equivalent and, since the animals are now in a forward condition, each lb of liveweight gain will require at least 2.25 lb of starch equivalent. We should also now allow 2 lb of starch equivalent for grazing so that for 1 lb daily gain the pasture must provide $(5 + 2.25 + 2) = 9.25$ lb of starch equivalent including 1.5 lb of protein equivalent. Provided growth is still satisfactory and the density of the pasture is such as to allow maximum food consumption, the animal, now consuming 19 lb of dry matter, will secure in its daily food 10.6 lb starch equivalent and 2.4 lb protein equivalent. Its live-weight gain will, therefore, now be at the rate of about $1\frac{1}{2}$ lb per day.

Suppose, however, that in the late summer or early autumn the nutritive value of the grass per 100 lb dry matter has fallen to 40 lb starch equivalent including 7 lb protein equivalent, and that the beast is eating 20 lb of dry matter per day, it will be consuming 8 lb of starch equivalent including 1.4 lb protein equivalent. The weight of the animal will be about 8 cwt and its requirement for maintenance 5.5 lb of starch equivalent, and to cover the muscular activity in grazing will involve the expenditure of 2.5 lb of starch equivalent on the deteriorated pasture, or a total requirement of 8 lb of starch equivalent per day. The weight of the animal must, therefore, remain stationary unless some concentrate is fed. Our calculation shows that even on a moderate pasture, provided there is no over-stocking, a beast of 6 cwt in the spring should attain a live weight of 7.5 to 8 cwt by the autumn without any supplementary feeding of concentrates.

(2) FATTENING 3-YEAR-OLD BULLOCKS OF ABOUT 10 CWT
LIVE WEIGHT ON GOOD PASTURE

A 10 cwt store bullock will eat about 23.5 lb of dry matter and will need 6.5 lb of starch equivalent for maintenance with a total protein equivalent of 1.5 lb per day. If in store condition, it will only need at first 2.5 lb of starch equivalent per lb liveweight increase, but this will soon increase to 2.75 lb or even 3 lb of starch equivalent as its condition improves to half-fat.

In the spring and early summer the pasture should provide $\frac{23.5 \times 50}{100} = 11.75$ lb of starch equivalent including $\frac{23.5 \times 12.5}{100} = 2.9$ lb protein equivalent, a deduction of 1 lb of starch equivalent must be made for the extra muscular effort in grazing. The starch equivalent left over for liveweight gain will, therefore, amount to $13.2 - 7.5 = 5.7$ lb, the protein equivalent being almost double the total requirement. The conclusion is that no concentrate need be given for the bullock to fatten at an average rate of 2 lb per day during the first half of the grazing season on pastures of good fattening quality, and they may even do a little better.

On pastures where experience has shown the need for supplementing the grass with concentrates to enable the cattle to reach a suitable finish for slaughter, feedingstuffs rich in carbohydrate should be used, since as little as 1 lb of dry matter of the grass supplies the necessary 1.5 lb of protein equivalent. The supplement should consist of crushed oats or barley, though a small proportion of the astringent undecorticated cotton cake might also be included should scouring be prevalent.

Supposing that after about two months the grass becomes somewhat restricted in amount on account of unfavourable weather conditions and the cattle are able to secure only about three-quarters of a full ration, say 18 lb of dry matter per head per day. The herbage may also have deteriorated so that it supplies only 50 lb of starch equivalent including 10 lb of protein equivalent, per 100 lb dry matter. What should be the nature and amount of the concentrate supplement needed?

The animals now average 11 cwt so that their maintenance requirement is 7 lb and the production requirement 3 lb of starch equivalent per lb liveweight gain, per day. Allowing again 1 lb of starch equivalent for grazing the total daily requirement for 2 lb liveweight increase becomes $7 + 1 + 6 = 14$ lb of starch equivalent. The contribution the unrestricted grazing will make amounts to $\frac{50 \times 18}{100} = 9$ lb of starch equivalent, so that the concentrate must provide $14 - 9 = 5$ lb of starch equivalent per head per day. The 18 lb of dry matter in the grass eaten will also supply 1.8 lb of protein equivalent which is more than ample. About 6 lb of maize or 8 lb of crushed oats should provide the necessary nutrients to enable the animals to maintain a daily gain of 2 lb per day and show a satisfactory finish.

SUMMER MILK PRODUCTION

EXTENSIVE GRAZINGS

The problems incidental to the nutrition of the dairy herd on ordinary extensively-grazed pastures will be considered first. These are pastures that are grazed continuously but never closely, the object being, if at all possible, to maintain a satisfactory bite. It is the common method adopted by the dairy farmer to insure against drought. Unfortunately the pasture frequently gets ahead of the grazing animal, particularly during the flush growth, with the consequent accumulation of varying amounts of coarse and dead material intermingled with the young growth. The nutritive value of such pasture gradually deteriorates in late summer and autumn.

EARLY SUMMER

Feeding tests have shown that 100 lb of dry matter in herbage from extensively-grazed pastures contains, during the early part of the grazing season, about 56 lb of starch equivalent, including 12.5 lb of protein equivalent. A cow eating 30 lb of dry matter from such herbage will, therefore, secure 16.8 lb of starch equivalent. Assuming the cow weighs 10 cwt and allows 1 lb extra starch equivalent for muscular activity in grazing, there should be available $16.8 - 7.5 = 9.3$ lb starch equivalent for milk production or enough to produce about 3.5 gal. This accords well with practical experience that no supplementary feeding is necessary on grass in the first half of the growing season with cows yielding 3 to 4 gal. The grass consumed will also supply 3.7 lb of protein equivalent thus leaving, after deduction of 0.7 lb for maintenance, 3.0 lb for milk production. This amount of protein equivalent is sufficient for at least 5-6 gal of milk.

The 5 gallon cow on such pasture will require supplementary food, but this need not contain much protein. Maize germ cubes will make a suitable supplement since they contain 84 lb of starch equivalent with only 10.4 lb of protein equivalent. Any carbohydrate-rich foods such as cereal grains will, however, provide the right balance, though care must be taken to keep down the bulk. The manner in which the bulk factor operates will be made clear in the following computation:

	<i>lb dry matter</i>	<i>lb starch equivalent</i>	<i>lb protein equivalent</i>
9 lb of equal parts of crushed oats and barley	7.7	5.9	0.7
1½ lb of crushed barley for effort in grazing	1.2	1.1	0.1
Total nutrients in supplement	8.9	7.0	0.8
Cow can still eat 23 lb of dry matter of grass	23.0	12.9	2.9
	31.9	19.9	3.7
Total requirements of 5 gal cow after allowing 1 lb extra S.E. for grazing . .	—	20.0	3.2

For a cow yielding more than 5 gal it will be necessary to feed a supplement richer in protein equivalent than cereals. Moreover the bulk of the grass sets a limit to the nutrients that the cow can consume. High-yielding cows on pasture fail to make full use of the grass since the amount has to be severely restricted and their requirements must be provided by concentrates even in early summer. This point will be dealt with later.

EFFECT OF ADVANCING SEASON

It is during the period of declining feeding value that the skill of the farmer must be directed towards deciding when and to what extent supplementary feeding is necessary. He must be guided chiefly by the condition, milk yield and milking capacity of each cow. Intelligent summer feeding is not possible without milk recording, for manifestly, in the matter of feeding concentrates it would be entirely uneconomical to treat all cows alike, irrespective of milk yield. Again, a cow is more likely to respond to supplementary feeding immediately after calving than in the latter stages of lactation.

With the arrival of autumn, the bulky coarse herbage may only supply sufficient nutrients for maintenance, but with suitable rainfall to encourage lush growth it should provide enough for maintenance plus the first gallon. If 100 lb of dry substance in the grass supplies 40 lb of starch equivalent, including 7 lb of protein equivalent, a dairy cow eating a full ration of 30 lb dry matter will secure 12 lb of starch equivalent, including 2.1 lb of protein equivalent. The actual requirement of a 10 cwt cow yielding 1 gallon of milk is 9 lb of starch equivalent, and to this must be added 3 lb of starch equivalent for walking about, making a total of 12 lb or the exact amount consumed.

For cows yielding more than 1 gal of milk per day, supplementary feeding concentrates will obviously be necessary. A 10 cwt cow yielding 3 gal of average milk, and assuming that 3 lb of starch equivalent is necessary for walking about and grazing, will require $6.5 + 3 + (2.5 \times 3) = 17$ lb of starch equivalent, including $0.7 + (0.5 \times 3) = 2.2$ lb of protein equivalent. These requirements could be met as follows:

	<i>lb dry matter</i>	<i>lb starch equivalent</i>	<i>lb protein equivalent</i>
4 lb of crushed barley for energy in grazing . . .	3.4	2.8	0.3
4 lb of crushed oats for 2nd gal of milk	3.5	2.4	0.3
3½ lb of balanced milk production mixture for 3rd gal	3.1	2.5	0.5
The concentrates supply . . .	10.0	7.7	1.1
Cow can still eat 22 lb of dry matter of grass	22.0	8.8	1.5
Nutrients in complete diet . . .	32	16.5	2.6
Actual requirements	32	17	2.2

Supplementary feeding in the autumn should be sufficient to maintain the yield since once it declines it is not easy to restore it to its former level.

SUPPLEMENTARY FORAGE CROPS

In districts subject to drought it is a wise precaution to plan a succession of green crops for feeding during a period of scarcity. The natural supplement feed is grass silage, made at the flush period when the pasture is running away from the animals. About 20 lb will supply 2.5 lb of starch equivalent and 0.5 to 0.6 lb protein equivalent.

Green lucerne is another suitable supplement available during the summer up to early September about 25 lb per gal being fed on pasture. Other useful crops for summer soiling are clover and ryegrass, oats and vetches, green maize, kohlrabi and cabbage. About 20 lb of green oats and vetches will provide for a gallon of average milk.

INTENSIVE OR CLOSE GRAZING

This is under a system of rotational or strip grazing, using the electric fence, so that the full potentialities of pastures for milk production can be realised. The interval of growth between each successive close grazing can then be arranged in accordance with the meteorological conditions so that the grass

is grazed at a height of 4 to 5 in., and wastage due to trampling and spoilage is at a minimum. In this way the deterioration in nutritive value with advancing season is largely prevented.

During the period preceding the flush growth, 100 lb of dry matter of young leafy grass contains about 70 lb of starch equivalent, including about 18 to 20 lb of protein equivalent. A full ration of 30 lb dry matter would supply sufficient starch equivalent for the maintenance of a 10 cwt dairy cow and the production of about 5 gal of milk, and sufficient protein equivalent for maintenance plus 9 gal. During the flush period of growth, however, the nutritive ratio widens so that the dry substance contains about 66 per cent of starch equivalent, including about 13 per cent of protein equivalent. Given favourable growing conditions and close grazing the grass need not deteriorate in feeding value, and may indeed show an improvement in protein equivalent towards the end of summer. A full ration of 30 lb of dry matter of this herbage supplies 20 lb of starch equivalent, including 3 lb of protein equivalent, so supplying the requirements of a 5 gal cow of 10 cwt live weight as follows:

	<i>lb starch equivalent per day</i>	<i>lb protein equivalent per day</i>
Required for maintenance .	6.5	0.7
Required for 5 gal milk .	12.5	2.5
Required for effort of grazing	1.0	—
	—	—
	20.0	3.2
	—	—

Suppose, on the other hand, that a 5 gal cow is only able to graze sufficient herbage to provide 25 lb of dry matter. Her further requirements could be met as shown below:

	<i>lb dry matter</i>	<i>lb starch equivalent</i>	<i>lb protein equivalent per day</i>
25 lb grass dry matter .	25.0	16.6	3.2
3 lb flaked maize .	2.7	2.5	0.3
2 lb Egyptian cotton cake .	1.8	0.8	0.4
	—	—	—
Total .	29.5	19.9	3.9
Requirements as shown above	30	20	3.2

For cows yielding more than 5 gal of milk it would be logical to assume that the supplementary food should take the form of a balanced milk production mixture for each gallon of milk above the fifth, but difficulties due to bulk would soon become apparent in loss of condition by the cow and lowered milk yield. A 9 gal cow, to use an extreme case, could scarcely be expected to consume $3.5 \times 4 = 14$ lb of balanced concentrates in addition to 150 lb of green leafy herbage providing 30 lb of dry matter. Little difficulty is experienced until the yield rises above 5 gal or perhaps 6 gal if the cow has the food capacity or appetite, but beyond this the bulky nature of grass as a concentrate makes it necessary to restrict the hours of grazing, and the farmer has to rely more and more on oil cakes and meals to provide the necessary nutrients.

Suppose we have a 3 gal cow of 11 cwt live weight grazing on pasture and that because the grass is scarce she is able to secure only a half ration of

16 lb of dry matter per day. This would supply $\frac{16 \times 66}{100} = 10.6$ lb of starch equivalent, including 2.1 lb of protein equivalent. Ignoring the supply of starch equivalent needed to furnish the energy expended in grazing, such an animal requires per day $7.0 + (2.5 \times 3) = 14.5$ lb of starch equivalent, including $0.75 + (0.5 \times 3) = 2.25$ lb of protein equivalent. The supplement needed to maintain milk yield would therefore amount to 3.9 lb of starch equivalent. This could be met by feeding 5.5 lb of crushed barley or 6.5 lb of crushed oats. To supply the energy for walking about and grazing, which could be assumed to amount to 1 lb a day of starch equivalent, a further 1.5 lb of crushed barley or 2 lb of crushed oats, would be adequate.

For more detailed information on grassland management see Bulletin 154*.

Feeding Calves

CALVES grow quickly and may be expected to double their weight in the first two months of life. Until quite recently it was thought essential that milk feeding in one form or another should be continued for at least two months and preferably for three months, the total consumption amounting to 50 to 60 gal per head. Experiments have now shown that the calf is far more adaptable than this regime would suggest in that milk substitutes can be used equally successfully and from an early age. But no calf should be deprived of its mother's colostrum during the first 3 or 4 days of life. The colostrum is protective against certain diseases such as scours, is slightly laxative and is a rich source of proteins and of vitamins A, D and E. Again attempts to substitute dry foods for whole milk during the first fortnight have not been successful.

The rumen is at first non-functional, the highly digestible colostrum and milk passing direct into the fourth or true stomach and there coming into contact with the digestive enzymes of the gastric juice. Recent investigations have shown, however, that the rate of development of the rumen can be appreciably accelerated by restricting the fluid foods at an earlier age and providing appropriate solid foods. Many calves can be weaned at 3 weeks of age, their total milk consumption amounting to only 10 gal, and most calves can be weaned at 5 weeks of age, though it is improbable that the rumen is functioning as fully as in the adult animal at this early stage. For the first six to eight weeks of life the calf is a non-ruminant and is dependent on its food for the B complex vitamins subsequently synthesized.

Opinions differ as to the most economical rate of growth to aim at, and maximum growth is not considered by some authorities to be physiologically desirable in calves intended for the dairy herd. From an economic standpoint there is also much to be said for limiting the growth rate of at least some types of beef calves. It should be borne in mind that over-feeding may be as harmful as under-feeding, and that changes in diet should be made gradually to avoid digestive disturbances.

Bulletin 154, *Grassland Management*. Price 4s. 6d. (by post 4s. 11d.), obtainable from H.M. Stationery Office or through any bookseller.

The highest growth rates during the first 3 months are usually reached by calves of beef breeds and their crosses, when running with their dams. This may average 1.75 lb per day. A close approach to this figure can be obtained in the case of bucket-fed beef calves, intended for slaughter at 18–20 months of age. A more usual and possibly more economical gain may be aimed at is 1.3 to 1.5 lb per day, and this is probably the optimum rate for dairy calves.

It is impossible to illustrate the large number of variants practised in calf rearing, but it may be of interest to quote three contrasting systems of feeding, namely, whole milk; milk equivalent and “dry” feeding.

The provision of good quality hay to promote cudging, develop appetite and supply vitamins A and D is common to all systems.

MULTIPLE SUCKLING OF WHOLE MILK

In this system, calves are allowed to suckle cows in groups of 4, 3 or 2 for a matter of two to three months, in the course of which they consume anything from 70 to 100 gal of milk. Concentrates, of the type described below as rearing mixture, are fed from about 3 weeks onwards in quantities rising from 1 lb to 3 or 4 lb per day.

This is a system suited to rearing beef calves on farms from which milk is not readily saleable, but it calls for a good deal of managerial skill in controlling milk intake.

At one month of age the animal's daily consumption may be put at about 1 lb each of hay and concentrates, and 1 gal of milk — a total diet of rather more than 2.5 lb S.E. and containing about 0.5 lb protein equivalent. As the calf is then growing at about 1 lb live weight per day its food conversion ratio is very high.

MILK EQUIVALENT

All milk equivalents are based on dried separated milk or by-products such as buttermilk or whey. Some proprietary mixtures are reinforced with emulsified fats.

Though growth rates are seldom as high as those which can be obtained with whole milk, calves thrive on a diet of milk equivalent even if it is fed immediately after the flow of colostrum ceases. Milk powders made from dried separated milk or mixtures of dried separated milk, buttermilk and whey appear to be fully as efficient as powders in which fats have been incorporated.

A varying mixture of concentrates with a crude protein content of about 16 per cent is provided. A mixture of 85 per cent cereals and 15 per cent of a high protein concentrate, such as decorticated ground-nut meal, soya-bean meal or linseed cake meal, to which 3 per cent of mixed minerals (limestone, bone meal and salt) is added, has been found satisfactory.

Liquid feeding can be stopped abruptly at about 8 weeks, but it is often continued for 10 or even 12 weeks.

DRY FEEDING

As the object is to get the calf on to solid food as quickly as possible every effort is made to tempt the animal to eat it. The best appetizer so far discovered is molasses, fed in the form of impregnated peat.

The following method has been evolved at the Rowett Research Institute. After 3 days on colostrum, milk is fed up to a maximum of 8 lb daily for 100 lb of birth weight, e.g., 6 pints for a Friesian. Water is fed in limited quantities from a bucket. At 10 days, the calf is introduced to an early weaning concentrate of the following type (to which minerals and vitamins A and D are added):

Early weaning mixture (parts by weight)*

Flaked maize	8
Crushed oats	6
Molassine meal	3
Dec. G.N. cake	2
Fish meal	1

Strong calves can be weaned at 3 weeks of age, provided they are then getting 0.5 lb of this mixture daily. Weaker calves continue to receive milk for a further week or fortnight.

The allowance of concentrates is stepped up after weaning to a maximum of 4 lb daily at 8 weeks. At 12 weeks the early weaning mixture is gradually replaced by a rearing mixture.

VEAL CALVES

A few words may be added about the nutrition of the veal calf. The objective in feeding a calf for the veal market is to convert as much milk as possible into flesh. Water is therefore withheld and sometimes neither hay nor concentrates are fed.

Calves of the larger breeds can be induced to drink 2 gal of milk per day at the time they are 6 weeks old, and much larger quantities if they are kept until they are 3 months old. As a rule they are sold at 8–10 weeks of age, when they might weigh 200 lb live weight or 110–120 lb dead weight. Conversion rates of 1 lb live weight per gal of milk may be obtained. Lower rates of growth and of conversion are, however, common and risks of casualties arising from over-feeding are considerable.

Somewhat similar returns are obtainable from feeding separated milk. The main difficulty in utilizing this by-product on a large scale is the need to introduce a preserving agent. Studies are proceeding in the use of separated milk preserved with a small quantity of formalin.

For a fuller treatment of the subject the reader is referred to Bulletin No. 10 "Calf Rearing"† on which the above notes are largely based.

* In the course of their experiments workers at the Rowett found that aureomycin or terramycin added at the rate of 1 g per cwt food improved the calves' appetite and hence their growth rate, and also lessened the incidence of scour.

† Bulletin 10, *Calf Rearing*. Price 3s. 6d. (by post 3s. 4d.), obtainable from H.M. Stationery Office, or through any bookseller.

Influence of Foods on the Composition of Milk

THE composition of milk is influenced by many factors, some of which are genetic, some physiological, some nutritional. Probably breed is the chief of these. Until recently most authorities believed that, provided the diet was adequate and balanced, feeding had very little effect; under-nutrition reduced yield, but the composition of the milk remained virtually unaffected.

Naturally some exceptions were recognized. It became known, for instance, that feeding large amounts of cod liver oil reduced the percentage of fat in the milk and that this effect persisted for some time after the feeding of the fish oil ceased. Again, it was common experience that when cows were turned out to grass in the spring the percentage of fat in their milk might drop for a time, by as much as 50 per cent. On the other hand, certain feeds such as coconut or palm kernel cake were reputed to have a specific effect in raising the percentage of fat in the milk, though the amount that had to be fed to bring about any worthwhile effect was above the economic level of feeding. Incidentally, these two vegetable foods are unique in that their oil content is abnormally rich in short-chain fatty acids.* In addition to this it was recognised that the character of the butterfat could be influenced by the type of food fed, certain feeds producing soft fat and others hard fat. The pigments in the food also had an effect on the colour of butterfat.

An interesting discovery was, however, reported from America in 1933. It was demonstrated that the fat content of milk could be varied by as much as 60 per cent by simply changing the physical characteristics of the diet without in any way altering its nutritive value as far as chemical composition was concerned. It was found that if the coarse fodder or roughage content of the diet was reduced below a certain point, a marked fall in the percentage of fat in the milk occurred, although the diet provided more starch equivalent and protein equivalent than was necessary. The same effect was obtained when the roughage supply was normal if, before feeding, the whole diet was ground in a hammer mill and cubed. On restoring the roughage to what was normally fed in the first instance or, in the second case, when the roughage was again fed long, the fat percentage was quickly restored to its normal level. It was, therefore, demonstrated conclusively that the cow's ration does beyond doubt influence the fat percentage in the milk, and also the percentage of solids-not-fat, since these constituents also varied in the same general manner as the fat. On the basis of these experiments it was concluded that the activity of the rumen microflora was in some way associated with the composition of the milk. The actual connection could not be explained at the time and the significance of the discovery was therefore not appreciated.

It has been known for a long time that the bacteria in the rumen ferment the food carbohydrates and crude fibre and that the end products are simple

* The short-chain fatty acids have only a few carbon atoms so that they have small molecules. These carbon atoms are strung together like the links in a chain, hence the term short-chain fatty acids. There are other more complex fatty acids with 17 carbon atoms linked to each other therefore forming long-chain fatty acids. They are called fatty acids because many of them occur naturally in fats and oils such as butter and cod liver oil.

ds like acetic, propionic and butyric, which are quickly absorbed into the food stream. Research workers have recently proved beyond doubt that these acids, which were previously considered of no food value, are in fact made by the mammary gland and built up into larger molecules which then become part of the fat molecules. The process is dependent on the presence in the blood stream of a small amount of food fat to supply the longer and more complicated fatty acids in butter fat. This discovery of the significance of short-chain fatty acids in producing butterfat explained several hitherto unsolved mysteries. Thus when cows are turned out to grass there is a sudden and profound change in the nature of the rumen contents and the bacteria require time to become acclimatized to their new food so that the fat in the milk undergoes a temporary fall. If a little hay is fed to the cows, so as to bring about a more gradual change, then the upset of the fat metabolism is greatly lessened. A secondary effect would be that the hay, by remaining in the rumen for a longer time than the easily fermentable grass, would serve as a more durable source of fatty acids for fat synthesis. There are still many questions concerning the nutrition of the rumen microflora that are not understood. It has been found for example, that the inclusion of flaked maize in the concentrates tends to lower the fat percentage in the milk and that when crushed oats or barley are substituted for the maize the fat is soon restored to normality. Milk production is brought about by a series of physiological processes of a complex nature which are governed by the interaction of several factors.

The solids-not-fat content of milk has recently received considerable attention. The work has been stimulated by the frequency with which samples of milk with low solids-not-fat are being delivered to creameries and also by the fact that some authorities consider the milk proteins, lactose and ash to be of greater relative importance in human nutrition than the fat percentage. The incidence of low solids-not-fat varies in different parts of the country. It is generally more prevalent in late winter and early spring, during the period that has become known as the "hungry gap", but in parts of Scotland, on the other hand, it has been reported that up to 50 per cent of the in-coming milk delivered in August and September may have a solids-not-fat content of less than 8.5 per cent, although the cows are at grass and receiving some supplementary food. A recent examination of these low solids-not-fat samples indicated that the depression was due almost equally to the low protein content of the milk and to a lowering of the lactose content, the reduction in the ash percentage being of little significance. There is some evidence that the solids-not-fat content of milk can be influenced by the energy intake; an increase in the starch equivalent fed has been shown to restore the protein level so that the solids-not-fat content is brought back to normal.

A farmer producing milk of low solids-not-fat content should therefore ascertain whether by feeding a little more starch equivalent the value can be restored to normal. It may also be necessary to feed a little more protein equivalent, though it is interesting to note that the percentage of casein in the milk is directly related to the starch equivalent of the ration and not to the protein content. The marked improvement in solids-not-fat brought about when cows producing milk deficient in these constituents are turned out to grass in the spring is still the subject of investigation.

The level of nutrition during the dry period has an influence on composition of the milk. Due to the relatively better condition of the cow the milk produced immediately after calving may contain as much as 0.6 per cent more fat than that of cows receiving inadequate rations during the dry period. Finally, the farmer must realise that the age of his cows and whether they are pregnant or not are important factors affecting the composition of milk.

Rations for Sheep

FEEDING STANDARDS

The accompanying table supplies all the data necessary for calculating the rations of sheep of differing live weights. The figures apply only to sheep kept under lowland conditions. No corresponding information is at present available for sheep reared under hill and mountain conditions.

TABLE 8. *Feeding Standards for Sheep **

Live weight	Appetite dry matter per week	Maintenance requirement per week		Production requirement per lb live weight increase S.E.	Total protein equiv. requirement for maintenance and production per week
		S.E.	P.E.		
<i>lb</i>	<i>lb</i>	<i>lb</i>	<i>lb</i>	<i>lb</i>	<i>lb</i>
60	14.5	6.25	0.24	} 1.5	} 1.5
70	16.2	7	0.28		
80	17.9	7.75	0.32	} 1.75	
90	19.1	8.25	0.35		
100	20.4	9	0.38	2	} 1.75
110	21.7	9.5	0.42	2.25	
120	22.9	10	0.46	2.5	
130	24.2	10.5	0.50	2.75	
140	25.5	11	0.54	3	
150	26.8	11.5	0.58	3.5	
160	28.0	12	0.62	3.75	
170	28.9	12.5	0.66	4	
180	29.8	13	0.70	4	
190	30.6	13.5	0.74	4	
200	31.5	14	0.78	4	

* NOTE.—(1) No attempt is made in the table to state the requirements of sheep below 60 lb live weight. Studies of energy metabolism have shown that the “surface law” is not applicable to lambs, and that it would therefore be incorrect to attempt to deduce, on the basis of that law, the maintenance requirements of sheep below 60 lb live weight. The care of lambs during the period they are with the ewes must remain, for the time being at any rate, a matter rather of the feeder’s art than of the strict application of scientific knowledge.

(2) The figures in the column showing the appetites of sheep at different live weights are meant to apply to sheep subsisting on typical winter rations such as kale (or roots), hay and concentrates. Sheep on pasture, however, will consume a larger amount of dry matter per day than when on the customary winter diets, and for grazing sheep, the appetite data should be increased by 15 to 25 per cent, according to the quality of the grass.

It is not possible to condense into a few words all that is implied in the phrase "lowland sheep farming", and the following general reference must suffice. During the autumn the ewes are run with the ram on grass or clover leys, and are maintained through the winter on grass, roots or green crops with hay supplement. In the last four or five weeks before lambing, the ewes generally receive in addition a small allowance of concentrated food, the amount varying from 0.25 to 1 lb per head per day according to their condition. At lambing time in spring, the ewes continue to receive about 1 lb per head per day of a balanced concentrate mixture in addition to hay and green food (or roots), and the lambs are allowed access through creeps to a suitably balanced concentrate mixture. Throughout the summer, the lambs are kept on grass, or on clover leys, or on other green crops specially grown for the purpose. Some, with the help of a supplement of concentrates, may be pushed on rapidly for sale as fat lambs, whilst the remainder may be kept either for breeding, or for fattening during the winter on roots or green crops with a supplement of hay and concentrates.

Brief reference may be made to the practice of flushing the ewes before they are put to the ram. This practice consists of giving the ewes an extra supply of good food some two or three weeks before tupping. This may be done by changing them to a field with an abundance of good keep on it, such as fresh grass or clover ley aftermath. Alternatively, green fodder may be started to them, and if neither of these methods is feasible, the ewes may be given a supplement of 2-3 lb of oats and cake per head per week. By this means, the ewes, which have been subsisting on a rather poor plane of nutrition during summer and early autumn, are brought into rapidly improving condition for the ram. The flushing causes them to mature a greater number of egg cells, and in this way the proportion of twins or triplets at lambing is likely to be increased.

The following examples serve to illustrate the use of the data in the table of feeding standards:

HOGGETTS (TEGS) FATTENED IN THE WINTER

The problem is to determine the quantity and composition of the concentrated supplement to be fed to hoggets that are folded on roots or green stuff during the winter and are receiving in addition about 4 lb of hay per head per week. Such hoggetts will average about 80 lb live weight in October. The table shows that they will eat about 18 lb of dry matter per week. Their maintenance requirement is 7.75 lb of starch equivalent per head per week, their total protein equivalent requirement about 1.75 lb and their production requirement 1.5 lb of starch equivalent per lb of liveweight increase. The animals should increase in liveweight at the rate of 2-2.5 lb per week.

Let us assume that 90 lb of marrowstem kale and 4 lb of hay are allowed to the tegs per head per week. The choice of hay will be between meadow hay and leguminous hay (e.g., clover hay, lucerne hay, sainfoin hay, etc.). Fattening tegs usually prefer legume hay, particularly if it has been cut before the stems have developed a woody character. Such roughage is valuable on account of its relatively high protein and mineral content. For purposes of comparison, however, two rations will be computed, one of which contains good meadow hay and the other a good grade of clover hay.

<i>Ration 1 (using good meadow hay)</i>					<i>Starch equivalent</i> <i>lb per week</i>	<i>Protein equivalent</i> <i>lb per week</i>
90 lb marrowstem kale	.	.	.	.	8.2	1.26
4 lb good meadow hay	.	.	.	.	1.4	0.14
					9.6	1.40
Standard requirements for 2.5 lb L.W.I. per week					11.5	1.75
Supplement should contain					1.9	0.35
<i>Ration 2 (using good clover hay)</i>						
90 lb marrowstem kale	.	.	.	.	8.2	1.26
4 lb good clover hay	.	.	.	.	1.6	0.28
					9.8	1.54
Standard requirements for 2.5 lb L.W.I. per week					11.5	1.75
Supplement should contain					1.7	0.21

It is clear, therefore, that if the tegs consume 90 lb of kale and 4 lb of hay per week, they will still require, in order to put on 2.5 lb of liveweight increase per week, further food containing about 1.8 lb of starch equivalent. If meadow hay is used as the roughage, the supplement should provide not less than 0.35 lb of protein equivalent, but should clover hay be used instead the extra protein equivalent required is reduced to 0.21 lb. This sparing effect of leguminous hay on the oil cake to be included in the concentrate supplement is brought out in the accompanying examples of suitable mixtures. In general these are made up from cereals, such as barley, maize, flaked maize, maize-germ meal, etc., to which some kind of oil cake is added to give the requisite balance and to increase palatability. Leguminous grains such as beans and peas, are also often included.

Concentrate supplement in Ration 1:

1. 2.5 lb per week of a mixture of equal parts by weight of decorticated ground-nut cake, flaked maize and crushed barley, supplies almost exactly 1.9 lb of starch equivalent and slightly more protein equivalent than is actually required, namely 0.45 lb. Despite this, however, the proportion of oil cake in the supplement need not be reduced, since to do so would mean some loss of palatability.
2. 2.5 lb per week of a mixture of 2 parts by weight of linseed cake and 1 part each of flaked maize and crushed barley contains the required 1.9 lb of starch equivalent, including 0.38 lb of protein equivalent.

Concentrate supplement in Ration 2:

1. 2.3 lb per week of a mixture of 1 part by weight of decorticated ground-nut cake and 2 parts each of flaked maize and crushed barley, supplies the 1.7 lb of starch equivalent needed per week, including 0.33 lb of protein equivalent. This again is slightly more protein than is actually required.
2. 2.3 lb per week of a mixture of equal parts by weight of linseed cake, flaked maize and crushed barley has a starch equivalent content of 1.8 lb and includes 0.32 lb of protein equivalent.

The only question remaining to be settled is whether the total ration per week of 90 lb of kale, 4 lb of hay and 2.3 lb of concentrates comes within the

animal's capacity for consuming food. This capacity, as shown in the table of standards, is about 18 lb of dry matter per week, and the ration supplies $12\cdot6$ (kale) + $3\cdot4$ (hay) + $2\cdot0$ (concentrates) = 18 lb of dry matter. From the bulk standpoint, therefore, the ration is adjusted to the appetite of an average sheep of 80 lb liveweight. Such an animal, when receiving the amounts of kale and concentrates in the ration and allowed to eat as much kale as it likes, may be expected to gain at the rate of about 2.5 lb per week. Should a particular sheep have a larger appetite than the average, it will consume more kale and probably make slightly larger gains. An animal with a smaller appetite than the average will, on the other hand, tend to eat less kale, and its rate of liveweight increase will be under 2.5 lb per week. Considerable variations in this respect are naturally noted in farming practice, the individual gains frequently ranging from 1 to 3 lb, with an average of rather more than 2 lb per week.

To reduce the risk of the greedy feeders picking out more than their fair share it is desirable to introduce the oil cake in meal form into the concentrate supplement; this in practice is usually fed at the rate of 0.25–0.3 lb per head per day for the first month, rising thereafter to about 0.75 lb during the 4–5 months of fattening.

The foregoing calculations have made it clear that when tegs are folded on kale, their requirement for oil cake or other protein-rich food is not very great, particularly when leguminous hay is included in the dietary. The need for oil cake becomes even less marked in the later stages of fattening, and the following computations serve to illustrate this point. A teg of 100 lb liveweight, fattening at the rate of about 2 lb per week, requires, per week, 2 lb of starch equivalent for maintenance, and $2 \times 2 = 4$ lb for the liveweight increase; i.e., a total of 13 lb of starch equivalent. The weekly ration must contain not less than 1.75 lb of protein equivalent and not more than 20.4 lb of dry matter.

Two possible methods of meeting these requirements are shown below. It will be noted that the concentrate supplement consists wholly of cereal, and despite the exclusion of oil cake, the ration containing clover hay supplies protein equivalent somewhat in excess of actual requirements. The use of oil cake in the supplement in such circumstances could only serve the purpose of enhancing the palatability of the ration.

Ration 1 (using good meadow hay)

	<i>Dry matter</i> <i>lb per week</i>	<i>Starch equivalent</i> <i>lb per week</i>	<i>Protein equivalent</i> <i>lb per week</i>
90 lb marrowstem kale . .	12.6	8.2	1.26
5 lb good meadow hay . .	4.3	1.8	0.20
3 lb crushed barley . .	2.6	2.1	0.20
1 lb flaked maize . .	0.9	0.8	0.09
	20.4	12.9	1.75
Standard requirements . .	20.4	13.0	1.75

Ration 2 (using good clover hay)

90 lb marrowstem kale . .	12.6	8.2	1.26
5 lb good clover hay . .	4.2	2.0	0.35
4 lb crushed barley . .	3.4	2.8	0.26
	20.2	13.0	1.87
Standard requirements . .	20.4	13.0	1.75

When tegs are folded on roots instead of kale, however, the concentrate supplement must contain a higher proportion of oil cake to off-set the relative poorness of roots in protein. This is made clear by re-calculating the foregoing ration for the 100-lb sheep, gaining at the rate of 2 lb per week, using swedes this time instead of kale. It will be noted that whereas with kale the supplement could, if desired, consist wholly of cereal at this stage, it must, in case of swedes, contain some oil cake, and when high-protein oil cake is selected, this should form one-quarter of the weight of the total concentrate.

	<i>Dry matter</i> <i>lb per week</i>	<i>Starch equivalent</i> <i>lb per week</i>	<i>Protein equivalent</i> <i>lb per week</i>
110 lb swedes	12.6	8.1	0.77
5 lb good clover hay	4.2	2.0	0.35
4 lb concentrate supplement*	3.5	3.0	0.61
	20.3	13.1	1.73
Standard requirements	20.4	13.0	1.75

Fresh sugar beet tops, free from superficial water are much higher in dry matter, starch equivalent and protein than swedes. When folded off in practice, however, they are apt to become wet and soggy and more or less contaminated with sand; as a result their feeding value per ton is almost identical with that of swedes.

EWES WITH LAMBS

The fundamental aspects of the nutrition of the ewe have not as yet been completely investigated and assumptions have to be made in respect of (1) the requirements of starch equivalent and protein equivalent for the production of a gallon of ewe's milk; (2) the average yield of milk from the ewe and (3) the measure of the appetite of the ewe in terms of lb dry matter.

Professor T. B. Wood assumed that the production requirement for milk formation in the ewe was 3 lb of starch equivalent, including 1 lb of protein equivalent, per gal, but a consideration of the composition of ewe's milk leads to the belief that the figure for the starch equivalent requirement is probably too low. Ewe's milk is very much richer in protein and fat than cow's milk. According to the investigations of Godden and Puddy, the milk of the ewe contains on an average 6.1 per cent of protein, 4.8 per cent of lactose and 7.4 per cent of fat, compared with 3.5, 4.6 and 3.7 per cent respectively for these constituents in the milk of the Shorthorn cow. An attempt may be made on the basis of these figures to assess the starch equivalent requirement per gal of ewe's milk. A simple calculation shows that a gal of ewe's milk of such composition contains about 5,580 C of energy, whereas Shorthorn milk contains only about 3,200 C per gal. Since 1 lb of starch equivalent furnishes 1,360 C of energy for milk production, it follows that the requirement per gal of average ewe's milk is $\frac{5,580}{1,360} = 4.1$ lb of starch equivalent. Further, since 0.5 lb of digestible protein is required per gal of cow's milk containing 3.5 per cent of protein, it may be inferred that the amount required per gal of ewe's milk containing 6.1 per cent of protein is $\frac{0.5 \times 6.1}{3.5} =$ about 0.9 lb of digestible protein.

* Consisting of 1 lb of dec. ground-nut cake, 1 lb of flaked maize and 2 lb of crushed barley.

For the purpose of guidance in the computation of rations for ewes in milk, therefore, the food requirement for the production of 1 gal of milk may be taken as 4 lb of starch equivalent, including 1 lb of protein equivalent.

Very few reliable determinations of the yield of milk from ewes with lambs have been made. The figure given by Professor Wood is from 2.25 to 3 gal per week, with an average of about 3 gal.

On the basis of the figures in the table of requirements, a ewe of 160 lb liveweight would be expected to consume about 28 lb of dry matter per week. The appetite data in the table, however, are not intended to apply to ewes with lambs, since during the period of suckling, ewes will consume considerably more than this amount. How much more has not as yet been established by exact experiment, and Professor Wood assumed the appetite of a 160-lb ewe with lambs to be about 40 lb of dry matter per week.

In view of the assumptions that have to be made, the account which follows of the computation of rations for ewes in milk must be regarded as somewhat speculative, for certain aspects of ewe nutrition still call for detailed investigation. Very little is known of their response to grass, so the calculations are based on ewes which return with their lambs from the lambing pens, on to folded kale or other succulent crop. Feeding is now directed towards milk production, so that they may do their lambs well. The ewes will probably weigh about the same as when they were tupped, say, about 160 lb, and their maintenance requirement will be 12 lb of starch equivalent, including 0.62 lb of protein equivalent, per week. An average ewe yields about 3 gal of milk per week and for this she will require, per week, $3 \times 4 = 12$ lb of starch equivalent, including $1 \times 3 = 3$ lb of protein equivalent. The total ration required to prevent the average ewe milking at the expense of her own bodily reserves must supply, therefore, 24 lb of starch equivalent, including about 3.6 lb of protein equivalent, per week. In addition to 140 lb of thousandhead kale, the ewes may be given clover hay at the rate of 8 lb per head per week. The problem is to calculate the amount and nature of the concentrate supplement that must be fed in conjunction with the foregoing allowances in order that the full requirements of the suckling ewes may be satisfied. The kale and hay supply the following nutrients:

	<i>Starch equivalent lb per week</i>	<i>Protein equivalent lb per week</i>
140 lb thousand-headed kale . . .	14.4	2.10
8 lb good clover hay . . .	3.1	0.56
	17.5	2.66
Standard requirements . . .	24.0	3.62
Supplement must contain . . .	6.5	0.96

Whilst they are suckling their lambs, therefore, the ewes must receive, in addition to the kale and hay, a supplement that supplies 6.5 lb of starch equivalent, including 0.96 lb of protein equivalent. The exact nature of the supplement will depend largely on the foods that are available and on their relative prices. Suitable foods for mixing are dec. cottonseed meal, dec. ground-nut cake, linseed cake, soya-bean cake, beans or peas, maize-germ meal, flaked maize, crushed cereals, etc. For example, a mixture of 1 part by weight of dec. ground-nut cake, 2 parts of flaked maize and 3 parts of crushed barley contains 75 per cent of starch equivalent, including 12.7 per cent of protein equivalent. An allowance of 8.75 lb of this mixture per week (i.e.,

1.25 lb per head per day) will therefore supply the requisite amount of starch equivalent (6.5 lb), including slightly more protein equivalent (1.11 lb) than is actually required by the minimum standards. The bulk of the ration in terms of dry matter per head per week, is 22.1 (kale) + 6.7 (hay) + 7.6 (concentrates) = 36.4 lb, and this should be within the capacity for food consumption of an average ewe of about 160 lb live weight.

Similarly, when it is desired to use linseed cake instead of high-protein cake, a mixture made by blending 3 parts of linseed cake, 2 parts of flaked maize and 6 parts of crushed barley contains 74.5 per cent of starch equivalent, including 12.4 per cent of protein equivalent, so that if the ewes are allowed 8.75 lb per head per week, this supplement would provide 6.5 lb of starch equivalent, including 1.09 lb of protein equivalent. The bulk of the ration again comes to 36.4 lb of dry matter per week. It is clear, therefore, that the feeding of 1.25 lb per head per day of either of the foregoing supplements, in addition to the given amounts of hay and kale, would enable ewes to maintain condition whilst rearing their lambs.

Although when folded on thousandhead kale, the ewes are able to obtain the major part of their requirement for protein from the green crop, supplements containing a higher proportion of oil cake or other protein-rich food will be needed when they are folded on roots. This follows from a consideration of the relative poorness of roots in protein compared with kale. The following computation will serve to clarify this point:

	<i>Dry matter lb per week</i>	<i>Starch equivalent lb per week</i>	<i>Protein equivalent lb per week</i>
160 lb swedes	18.4	11.7	1.12
8 lb good clover hay . .	6.7	3.1	0.56
12 lb concentrated supplement *	10.5	9.0	2.18
	35.6	23.8	3.86
Standard requirements . Up to	40.0	24.0	3.62

Rations for Pigs

IN order to feed his pigs intelligently the feeder must know something of the manner in which growth or development takes place, since certain parts of the body grow at a different rate from others, as the pig matures. The composition of the carcass changes markedly with increase in age and the proportion of muscle to fat can be influenced by the amount and nature of the ration fed.

At birth the pig is largely head, neck and legs with a short shallow body and poorly developed hindquarters. The amount of skeleton exceeds the amount of fat but this position is quickly adjusted and the amount of bone falls below that of both muscle and fat from about four weeks onwards. There is an extremely rapid acceleration in the rate of growth of fat from birth to 4 weeks, after which it drops appreciably. It is suggested that early fat deposition has as its object the regulating of the body temperature, the fat layer insulating the body against cold.

The growth of the pig at first involves mainly an increase in the structural tissues, both bone and muscle being earlier developing than fat, with

* Composed of equal parts by weight of dec. ground-nut cake, flaked maize and crushed barley.

earlier than muscle. The animal is building up its framework and it is important that its diet should contain adequate amounts of proteins and minerals, muscle being largely protein and water. The most marked change initially is an increase in length which is then followed by a deepening and thickening of the body.

Muscle has the greatest proportional rate of increase up to about 16 weeks. At this stage fat deposition is increasing and after 16 weeks the growth of fat rapidly overtakes that of muscle. At 24 to 28 weeks about 50 per cent more fat than muscle is being laid down in the body. According to one authority, by the time the pig has attained bacon weight its skeleton has increased by 10 times the amount present at birth, the muscle by 82 times, but the fat has increased its birth weight by 677 times. Kidney and flare fat grow in line with body fat and are the latest developing carcass tissue.

It is important to note that at 16 weeks of age or between 90 and 110 lb live weight, according to whether the breed is early or late developing and depending on the plane of nutrition, the rate of muscle building falls off appreciably and in consequence the need for protein in the diet also decreases. Since fat deposition now becomes the main feature of growth, and fat synthesis in the body originates from the starch and other carbohydrates in the food, the importance of carbohydrate concentrates in the diet is manifest. It will be apparent to the reader that whereas feeding up to about 100 lb live weight will have a negligible effect on fat deposition in the body, the subsequent plane of nutrition of the pig can have a considerable influence on carcass quality and finish. The thickness of the "streak" or "belly" is also an important measure in relation to the quality of the bacon carcass in that it provides an index of the size of the bacon rasher from this region. The thickness of the streak is a relatively late developing character, the increased thickness being mainly the result of fat deposition. There will therefore be a tendency for thin back fat to go hand-in-hand with thin belly streak.

The rate of increase in the length of the pig also falls off rapidly after the 16 weeks or 100 lb liveweight stage, but the chest continues to develop in depth at an increasing rate. There are conflicting views on the association between growth rate and length of carcass, some claiming that the longer type of pig has the faster growth rate. A more recent view is that a high plane of nutrition up to about 100 lb followed by a low plane gives the maximum opportunity for the skeleton to grow and for the lengthening of the carcass.

It will be realised that the digestion coefficients obtained when using cattle or sheep do not apply to simple-stomached animals like the pig. Incidentally, in the ruminant the crude fibre is the first nutrient to undergo disintegration and digestion, thus liberating the proteins for digestion in the true stomach, whereas in the non-ruminant the crude fibre is the last constituent to be digested, this taking place in the large intestine. Provided the crude fibre is non-lignified the pig can digest and utilize it almost as readily as the ruminant. A separate section is included in the Tables of composition giving the digestible nutrients available to the pig in various feedingstuffs.

Some feeders use generous amounts of barley meal with only moderate amounts of middlings, but others prefer it the other way round. In this connection, however, the higher feeding value of barley meal (71 lb *T.D.N. per 100 lb) compared with fine wheat feed (63 lb T.D.N. per 100 lb) should be

Total Digestible Nutrients which are defined as: % dig. protein + % dig. carbohydrate + % dig. fibre + % dig. oil $\times 2.25$.

taken into account. Some fine wheat feed is essential to lighten the mix and to improve its palatability, but too much makes the diet bulky.

Among the common substitutes for barley meal in the rations of pigs may be mentioned ground wheat, ground oats, maize meal, fl maize, cooked potatoes and roots, including fodder beet.

GROUND WHEAT

Ground wheat should be given coarsely ground and introduced gradually into the diet. It can then form 30 to 40 per cent of the diet of strong stock in replacement of barley meal.

GROUND OATS

Ground oats are rather fibrous for inclusion in pig rations and have a low T.D.N. than barley meal. They should be finely ground in suitable measure. They may be included up to 30 per cent of the ration.

PROTEIN REQUIREMENTS

A typical diet for a young weaner used to contain about 17 per cent of crude protein and this was reduced to about 13 per cent in the later stages of fattening. The fibre content of such a ration would be about 4.5 to 5 per cent. The main part of the protein was commonly provided by including in the ration of the young animal 10 per cent of white fish meal containing some 60 per cent of crude protein, the animal-protein food being omitted at about 150 lb and its place taken by 5 per cent of vegetable-protein food such as extracted soya-bean meal or extracted decorticated ground-nut meal.

There is no doubt that such allowances of high-protein supplement were very generous and designed to afford the most ample safeguard against the risk of protein deficiency. Indeed, it is possible to reduce quite substantially the amount of white fish meal fed to bacon pigs without affecting the rate of gain, economy of food conversion or the conformation and leanness of the carcass. Equally good results are obtained with all-meal rations supplying only 7 per cent of white fish meal up to 90–100 lb live weight reducing this gradually so that no high-protein food at all is fed from 120 lb to slaughter at 200 to 210 lb live weight. Beyond 100 lb live weight, a mixture of barley meal and middlings, together with 3 per cent of good quality grass meal or lucerne meal, normally provides sufficient protein to ensure the maximum rate of growth compatible with the net energy content of the diet. In a typical experiment, for instance, pigs on such a low-protein diet consumed over the entire period from 46 to 200 lb live weight, a total of no more than 8.8 lb of white fish meal per head, compared with 44.6 lb by animals on the higher-protein diet, containing 10 per cent white fish meal up to 150 lb live weight. It is true that the omission of white fish meal at 90 lb live weight caused the animals subjected to this treatment to be slightly less thrifty than the control animals over the period from 90 to 150 lb live weight, the ratio of barley meal, coarse middlings, lucerne meal and minerals supplying somewhat less protein than was needed for maximum growth at this stage. A more satisfactory comparison with the control pigs would have been obtained if the little protein supplement had been continued up to 120 lb live weight.

The vegetable-protein concentrates most commonly used to supplement the low-protein cereal mixtures are extracted-decorticated ground-nut meal

extracted soya-bean meal. The extracted meals must be used in pig feeding to avoid "soft" carcasses. The proteins in ground-nut meal have, however, a lower biological value than those in animal protein foods. In trials at Cambridge it was found that when extracted-decorticated ground-nut meal was used to replace white fish meal it was necessary to include it in the diet of growing pigs at the high level of 20 per cent in order to obtain maximum growth. The minerals in the white fish meal had also to be provided for by feeding a mineral mixture.

The proteins in extracted soya-bean meal have a somewhat better supplemental value and a diet containing 15 per cent of this vegetable-protein supplement gave as good results from the standpoint of growth and economy of food conversion, as those obtained on the diet supplemented with 7 per cent white fish meal. A diet containing only 4 per cent of white fish meal in conjunction with 6 per cent of extracted-decorticated ground-nut meal will give near maximum growth, and has the advantage of being much more palatable than a similar diet supplemented with 20 per cent of extracted-decorticated ground-nut meal. A mixture composed of 3 parts of white fish meal and 6 of extracted soya-bean meal will also replace 7 per cent of white fish meal, provided minerals are also fed. In both instances the white fish meal can be safely omitted after 90 lb live weight, the vegetable concentrate being continued up to 120 lb and no protein rich concentrate being fed thereafter.

Protein derived from a mixture of foods is more likely to have a good biological value than when single-protein foods are relied upon, since the deficiency of one may be corrected by the other, thus resulting in a better or more balanced supply of amino-acids. As an example, it is known that gelatine is useless when it forms the sole source of protein in the diet because of its deficiencies. When gelatine is, however, added to oats, it improves its nutritive value since the gelatine happens to contain some of the amino-acids that are lacking in the cereal protein. The feeding of a little animal protein is always a safeguard against deficiency in essential amino-acids. One word of warning about barley is necessary. Occasionally malting barley of very low protein content is dumped on the market and sold for feeding purposes. One such sample was found by the author to contain no more than 7.5 per cent of crude protein, in contrast with the normal 10 per cent in feeding barley. A feeder relying wholly on purchased barley meal should consider substituting 10 per cent of the barley with bean meal or pea meal, to safeguard the protein supply.

SUBSTITUTES FOR WHITE FISH MEAL

The following amounts of high-protein foods are needed to supply as much digestible protein as is contained in 10 parts by weight of white fish meal: beef meat meal 9.5; meat and bone meal 14.0; dried separated milk 18.6 lb.

Feeding meat meal usually contains about 60 per cent of crude protein and 20 per cent of mineral matter; when 10 per cent is included in the ration it will therefore replace white fish meal without the need of using a mineral supplement. Whale meat meal containing about 60 per cent of protein and about 16 per cent of mineral matter can also be fed at the 10 per cent level in lieu of white fish meal. A new grade of whale meat meal now available contains as much as 88 per cent of protein and only 2.1 per cent of ash so that a mineral supplement should be included when this grade is used.

The only home-grown protein-rich foods suitable for pig feeding are bean meal and pea meal. About 4 lb of bean meal will be needed to replace 1 lb of white fish meal plus 3 lb of barley meal. Bean meal contains about 3 per cent of minerals and a mineral mixture must therefore be included if it forms any appreciable proportion of the protein supplement. Beans and peas give rise to a hard white fat.

DAIRY PRODUCTS IN PIG FEEDING

Of the protein supplements that are used in conjunction with cereals and cereal by-products in the diet of bacon pigs, skim milk and separated milk undoubtedly give the best results. Separated milk contains about 9.4 per cent of dry matter of which 3.6 per cent, or rather more than one-third is protein. It can, therefore, be used to correct the protein deficiency of cereal grains. About 2 lb of dried separated milk, or the amount present in about 3 gal of the liquid by-product, will replace the proteins in 1 lb of white fish meal or 1 lb of cereal meal. Moreover, separated milk contains lactose which has a beneficial effect on the acidity and microflora of the gut and improves the absorption of lime and phosphate. The proteins of milk are balanced and of high nutritive value, so that less protein is necessary than when protein concentrates of vegetable origin are used.

Separated milk is most valuable in the diet of the younger stock and should be reserved for this purpose when the amounts available are limited. It is most important that the milk be pasteurized before feeding and should be guaranteed to come from attested dairy herds, so as to avoid the risk of infecting the pigs with tuberculosis. It is also recommended that the pasteurized milk should be fed *slightly* sour as freshly-separated milk tends to be costly in action when fed sweet. Excessive souring may lead to digestive disturbances but bulk quantities can be satisfactorily preserved for up to a fortnight by the addition of 0.1 per cent formalin. The question that the pig feeder often asks is what amount or proportion of skim milk has to be added to cereal meal so as to correct its deficiency in protein and produce a balanced diet. This point has received considerable attention from Danish workers since the diet fed in the Danish progeny testing stations is composed of barley meal and skim milk with suitable supplements of vitamins and minerals. It is, therefore, interesting to note that the Danish authorities provide the following guide to fix the cereal/milk ratio for pigs of differing live weights:

<i>Live weight</i> <i>lb</i>	<i>Skim* milk</i> <i>lb</i>	<i>Barley* meal</i> <i>lb</i>	<i>Live weight</i> <i>lb</i>	<i>Skim* milk</i> <i>lb</i>	<i>Barley* meal</i> <i>lb</i>
30	3	1	100	6.4	4.0
45	3.5	1.5	120	6.6	4.6
55	4.2	2.2	150	6.6	5.3
70	4.8	2.6	200	6.6	6.2
90	5.7	3.5			

By using these proportions no further protein-rich supplement is necessary. It is not essential that the cereal should be composed of barley meal only since a mixture of barley, fine wheatfeed, finely ground oats and maize meal will be equally suitable. On the other hand, by using a single cereal like barley, the labour and expense of mixing is avoided. Since the butterfat in

* A suitable mineral and vitamin supplement must also be included.

is removed from the separated milk, leaving behind only 0.1 per cent, the level of the fat soluble vitamins A and D will also be low. Green food will supply some vitamin A but it is safer to include a synthetic vitamin A and D premix in the food. The Danish authorities also recommend feeding between 5 and 10 g of a mineral mixture composed of 80 per cent chalk and 20 per cent salt according to the age of the pig, or 1 per cent of mineral mixture can be added to the barley meal. Very satisfactory liveweight gains and grading results have been secured on the skim milk-barley meal diet. A suckling sow receiving $1\frac{1}{2}$ to 2 gal of skim milk per day, the remainder of the diet being composed of cereal grains and wheatfeed, will require no further protein supplement.

It is important to note that whey is not a protein-rich by-product but a carbohydrate-rich food comparable on the dry matter basis with barley meal or maize meal. Most of the protein has been removed in the cheese. About 1 lb of whey (1.2 gal) are necessary to replace 1 lb of barley meal and excessive feeding of whey in the final stages tends to produce an over-fat carcass. The ration must supply the usual amounts of white fish meal, or other high-protein supplement, and the mineral deficiency of the whey should be corrected.

VITAMINS IN PIG FEEDING

With indoor-fed pigs it is an advantage from the standpoint of the supply of carotene (the precursor of vitamin A) and the maintenance of health to replace 2-5 per cent of wheatfeed by an equal weight of dried grass meal or berseem meal. Incidentally the dried grass also supplies a little riboflavin and niacin. It is not so essential to give green food when yellow maize forms part of the diet since the yellow pigment cryptoxanthin is also a vitamin A precursor. When artificially-dried green food is not available, a small daily allowance of fresh green food such as lawn mowings or kale will fulfil the purpose just as well. For early-weaned pigs it is essential to provide some vitamin concentrate as shown later.

It is unlikely that pigs on a normal diet will benefit from a source of vitamin B₁₂ and it is only after feeding a diet such as extracted soya beans and maize over a considerable period that deficiency is likely to occur. The requirement of the pig for vitamin B₁₂ is only about 1 mg per 100 lb meal. There may be a need for a little vitamin D during the shortest days if the pigery is dark. This vitamin ensures the proper calcification of the bones and is protective against rickets. A pint of cod liver oil per cwt of mixed meal, or a premix containing the synthetic vitamin, can be given, but it should be kept in mind that the requirement per ton of meal is only a fraction of a pound when supplied as the pure synthetic vitamin.

QUANTITATIVE RATIONING

It has long been the practice to allow young pigs the maximum of meal they will consume. All recent evidence supports the soundness of this practice.

A question that has received considerable attention, and is still under investigation at many centres, is the effect of plane of nutrition, or level of feeding after 100-120 lb live weight, on the growth of fat and conformation of the body and consequently on the "grading" of the pig. There is no doubt

that overfeeding at this stage, as happens with self-feeders, tends to produce an “over fat” pig and that undernutrition if carried to extremes will produce a pig of poor finish with excessive leanness. The feeder must avoid both extremes.

Undernutrition from the energy standpoint, or “restricted” feeding, is usually called, can be brought about in two ways. The first is naturally limiting the amount of food given each day, according to the live weight of the pig. This is difficult when pigs are fed in groups as some devour more than others. Another method is to dilute the food with bulky food of low feeding value so that although the pig is eating to appetite it will still consume a limited amount of energy. Restricted feeding improves the efficiency of food conversion; the saving of meal between 100 and 200 lb live weight can be of the order of 50 lb.

Restricted feeding if carried to excess can have several undesirable features. It will slow down the rate of growth, prolong the fattening period and increase the over-head expenses. It has also a tendency to produce soft fat.

Soft fat is undesirable from the standpoint of appearance, cooking, curing, storage and transport. The keeping quality of a soft carcass is poor since the fat readily turns rancid. When the pig is on a restricted diet not only is less fat deposited but a greater proportion of the fat laid down originates from the liquid and oily food fats. On the other hand, when the pig is fattening at a normal rate most of its deposited fat originates from carbohydrates in the food, and this type of fat is hard and firm giving the carcass a better appearance and quality.

Pigs on a restricted diet are at a less mature stage of development when they attain 200 lb live weight than pigs receiving a full diet. On a low level of feeding the ratio of tissue to fat in their growth is greater and in consequence each lb of gain will contain relatively more water. The saving in meal is largely a reflection of the higher amount of water in each lb of weight increase. We may therefore summarize by stating that the level of feeding up to about 120 lb live weight has little effect on the fatness of the bacon carcass, but that over-feeding from this weight to slaughter can result in over-fat pigs, and poor grading results. Underfeeding, if carried to excess can also have an equally undesirable effect on the quality and conformation of the bacon carcass. Suitable levels of feeding are suggested in Table 9.

TABLE 9. *Scale of meal supply for bacon pigs*

lb meal			lb meal		
Live weight (lb)	Scale A	Scale B	Live weight (lb)	Scale A	Scale B
20	1.1	1.1	100	4.6	4.1
30	1.6	1.6	120	5.3	4.6
40	2.1	2.1	140	5.9	5.1
50	2.5	2.5	160	6.4	5.6
60	3.0	2.9	180	6.7	6.0
80	4.0	3.5	200	7.0	6.0

A rough guide to the meal requirement of weaners is to allow each individual 0.25 lb of meal per week of age. In Scale A the meal supply

adjusted as to reach a maximum of 7 lb per head per day when slaughter weight at 200 lb has been attained. Experience has shown that baconers of live weight have no difficulty in consuming this maximum amount of meal and in making thrifty liveweight gains thereon. Other experts prefer to restrict the meal supply as in scale B, so as not to exceed 6 lb of meal, this being reached at about 170–180 lb live weight. The rather slower growth at finish is claimed to give better grading results.

EFFICIENCY OF FOOD CONVERSION

The figure known as the food conversion factor, or the efficiency of food conversion, throws valuable light on the degree of economy with which the feeding of pigs is being conducted. It represents the pounds of meal consumed per lb of liveweight increase, and is obtained by dividing the meal consumption in lb by the liveweight increase. It may be calculated on the basis of total food consumption and total liveweight gain for the whole period from weaning to slaughter or for any selected sub-period. As would be expected, the factor does not remain constant over the entire feeding period, but increases progressively as the pigs grow fatter and heavier. This is illustrated by the following figures from a Cambridge feeding trial in which the pigs were fed individually. The ration was a high-grade mixture of meals, fed in the form of a thick slop and in the amounts shown under scale A in Table 9 (p. 86) and the conditions of management were good.

Rates of liveweight increase and efficiencies of food conversion

	<i>Mean liveweight increase per day (lb)</i>	<i>Mean lb meal per lb live- weight increase</i>
From weaning to 90 lb live weight .	1.10	2.7
From 90 to 150 lb live weight .	1.50	3.3
From 150 to 200 lb live weight .	1.56	4.2
From weaning to 200 lb live weight.	1.35	3.4

When rations have to be made up from feedingstuffs of indifferent feeding value, or where housing conditions are poor the food conversion factor may rise to uneconomic levels. In a war-time experiment, for instance, 10 individually-fed pigs of 150 lb live weight were placed on a ration composed of 50 per cent of a mixture of fine bran and fine millers' offals (containing barley meal), 10 per cent of extracted decorticated ground-nut meal and 5 per cent of lucerne meal with 2 lb of a mineral mixture added per 100 lb of mixed meal. The animals, on an average, required 42.3 days to increase in live weight from 150 to 195 lb, the mean daily liveweight gain was no more than 0.7 lb, whilst the mean amount of meal consumed per lb of liveweight increase rose to the high value of 6.09 lb.

FEEDING SWILL

Household feeders scarcely need reminding of the useful part that swill played during the war, and is still playing, in the feeding of pigs. When compared on the basis of equal moisture content, a good grade of household swill or processed urban swill (the so-called "concentrated swill") is, on an average, quite equal to fine wheatfeed in feeding value. Investigations at Cambridge showed that 1 ton of a good grade of concentrated swill, containing about 32 per cent

of dry matter, has a feeding value for pigs equal to that of 0.3 ton of a mixture of 2 parts by weight of barley meal and 1 part of middlings (75 per cent extraction).

It should be emphasized that concentrated swill will only have this feeding value provided it is used correctly. It is not desirable that the swill should form the sole food of pigs, since this, in the author's experience, is very liable to lead to constipation. This danger can be avoided, however, by including fine wheatfeed in the ration. Pigs below 50 lb live weight should be given only small amounts of swill — just sufficient to accustom them to the taste. At this stage, all-meal feeding may gradually be replaced by the feeding of swill, balanced by the addition of wheatfeed and a small amount of high-protein supplement. A suitable balance would be obtained by incorporating 7–10 lb of white fish meal (or similar protein-rich food) and at least 20 lb of fine wheatfeed with about 2.5 cwt of concentrated swill (30–32 per cent of dry matter) or 3.25 cwt of ordinary household swill (20–25 per cent of dry matter). The fish meal may gradually be omitted from the ration at about 120 lb liveweight. Alternatively, swill may be used as the supplemental food, either alone or in conjunction with bulky farm crops or residues, in the Lehmann system of pig feeding (see below).

Perhaps the point requiring most emphasis at the present time is that raw swill *must by law be boiled for at least an hour before being fed to livestock*. Some pig feeders are apt to take this instruction too lightly, but careful sterilization of the material in this manner is an essential safeguard against the possible spread of disease, and failure to observe this precaution is exceedingly risky. Concentrated swill pudding, however, having been subjected to the requisite degree of heat during processing, may be fed without further heat treatment.

LEHMANN METHOD OF PIG FEEDING

Brief reference may now be made to a system of pig feeding introduced into this country from Germany in the years immediately preceding the outbreak of the war. By this method the young pigs after weaning are fed in accordance with the usual standards until they reach 50 lb live weight. At this stage they will be receiving 2.5 lb of meal per head per day, and from this live weight up to slaughter the daily allowance of the basal meal is kept constant at 2.5 lb per head. In addition to the meal, the pigs are now permitted to consume as much as they can of a supplemental diet of bulky, farm-grown products, such as cooked chat potatoes or potato silage, root crops, sugarbeet pulp or tops, green crops, including grass, lucerne or kale, market garden by-products, such as cabbage or sprout residues. Boiled swill may also form part or the whole of the supplemental food.

When the Lehmann method was first introduced into this country, it was thought that the basal meal must contain at least 30 per cent of high-protein food. A typical Lehmann basal meal contained 35 per cent of fine wheatfeed, 30 per cent of barley meal (or other cereal), 20 per cent of white fish meal, 10 per cent of extracted, decorticated ground-nut meal and 5 per cent of lucerne meal or grassmeal. From a consideration of the results of their investigations into the protein requirements of bacon pigs, however, Woodman and Evans at Cambridge formed the opinion that the conventional Lehmann basal meal was unnecessarily rich in protein. Instead of containing as much as 30 per cent of high-protein food, it need contain no more than 10 per cent

It is to say, equally good results should be obtained with an ordinary sow-
d-weaner ration containing 10 per cent of white fish meal, or its equivalent
other high-protein food. This inference was shown to be correct in a series
of trials in which cooked chat potatoes, potato slices and molassed beet pulp
were used as the bulky, supplemental foods, and the further conclusion was
drawn that if this is so when the bulky food consists of potatoes or sugar beet
pulp, both of which are poor in protein, it is also true when protein-rich
green fodders are used as the supplemental food. It will be noted that this
modification of the make-up of the Lehmann basal meal enables the most
troublesome feature of this system of pig feeding to be avoided, namely, the
difficulty of changing over, at 50 lb live weight, from a meal mixture con-
taining only 10 per cent of white fish meal to one containing as much as 30
per cent of high-protein food.

VALUE OF GRAZING FOR BACON PIGS

Digestion trials at Cambridge have demonstrated that 6-7 lb of young, leafy
grass, with a moisture content of about 80 per cent, are needed to provide a
pig with as much digestible organic matter as is contained in 1 lb of ordinary
pig meal. It might be thought, therefore, that when pigs are run out to grass,
there should be a saving of 1 lb of meal for every 6-7 lb of grass consumed.
This is not so, however, since the figure from the digestion trial takes no
account of the energy expended by the pig in roaming about, and in biting
and masticating the grass. For this reason, the net productive effect of
6-7 lb of grazed herbage is significantly lower than 1 lb of pig meal.

This is so even when the grass is mown for feeding to pigs. In a controlled
feeding test, the amount of high-grade young grass (moisture content = 80 per
cent) required for an effect on liveweight increase equal to that of 1 lb of pig
meal was found to be as much as 10.5 lb, the disparity between this figure
and that from the digestion trials being a measure of the energy expended
by the pig in dealing with the grass part of the diet. One group of pigs, after
reaching 50 lb live weight, was given a fixed allowance of 2.5 lb of suitably
balanced meal per head per day, and, in addition, young grass cuttings up
to the limit of appetite. Despite satisfactory food consumption these pigs
averaged only 0.79 lb of liveweight increase per day over a feeding period of
10 weeks, compared with 1.19 lb per day in the case of a comparable group
of pigs on an all-meal diet. The grass-fed pigs were fussy and restless, making
repeated visits to the troughs throughout the day and expending a great deal
of muscular energy in consuming the bulky grass allowance, a behaviour not
conducive to rapid and efficient fattening. The control pigs, on the other
hand, displayed the placid behaviour usually associated with pigs on a good,
all-meal diet.

Dried grass meal, fed in admixture with appropriate meals has been shown
to possess a feeding value predictable from its content of digestible organic
matter.

It must be kept in mind that a well-grown pig will not eat more than
14 lb of grass per day, so that even on the most favourable assumption,
a full grass ration cannot be equivalent to more than about 2 lb of pig meal.
Satisfactory rates of liveweight increase are to be realized with pigs on
grass, therefore, attention should be directed to ensuring that the animals

are consuming, besides the grass, an adequate ration of concentrated meal. No hard and fast rule can be given; the principle is simply to adjust the amount of supplementary meal to such levels as to enable the grazing pig to make the rate of gain desired by the pig feeder.

FEED REQUIREMENTS OF THE SOW AND HER LITTER

In-pig sows and gilts are often allowed to graze in the open since by providing grass or arable crops it is possible to make a worthwhile saving of concentrates. Sows can deal with bulky foods much more efficiently than bacon pigs. If we assume that a sow will graze between 14 and 20 lb of green herbage per day and that about 10 lb of fresh young grass will replace 1 lb of balanced meal, then the saving of concentrates will amount to $1\frac{1}{2}$ or 2 lb per day. This should therefore suffice to give an in-pig sow on grass a meal allowance of $2\frac{1}{2}$ to 3 lb depending on her condition, but this should be increased gradually to 4 lb in mid-gestation and finally to around 6 lb about 3 weeks before farrowing. A good deal more work needs to be done before the nutrition of the sow is placed on a really scientific footing. Much is left to the skill and judgment of the herdsman to keep the sows in good nutritive condition without putting on too much fat.

A rough guide to the amount of meal required by the suckling sow is given by the husbandry rule: 2 lb of meal per day for the sow with an additional allowance of 1 lb for each piglet in the litter. A safer guide, perhaps, is to adjust the size of the ration so that the condition of the sow is maintained, as far as possible, throughout the suckling period. Every pig feeder will know how difficult, if not impossible, this is with sows suckling large litters, the sow milking "off her back".

Since sow's milk is very rich in protein compared with cow's milk, it is important that the diet of the suckling sow should be rich in this constituent. The milk yield of individual sows varies considerably. Scandinavian workers found that from the second to the eighth week of lactation sows averaged 10.3 lb of milk per day, the maximum yield occurring within the first fortnight of farrowing. New Zealand workers found average yields of 14.4 lb with a peak yield at 5 weeks of lactation.

In order to encourage early growth, particularly with large litters, most pig feeders provide "creep feed" for the baby pigs from about 3 weeks onward when the milk yield tends to decline. Obviously the creep feed should be rich in protein, minerals and vitamins, and low in crude fibre.

ARTIFICIAL REARING OF BABY PIGS

This system of pig-rearing, originally developed in the U.S.A., has aroused considerable interest among pig-feeders in this country. The system has two main attractions. Theoretically it enables the rearing of three litters where previously there were only two, this being achieved by shortening the nursing period by early weaning, thereby narrowing the intervals between farrowing. In practice, 5 litters in 2 years are more commonly obtained. In the second place, by early weaning the sow is saved the strain of lactation which necessitates the feeding of extra food over two months in order to keep

the milk supply. It is also claimed that piglets reared artificially are more even and, when given as much as they can eat, make better live weight at 8 weeks than when naturally fed by the sow.

The original suggestion of removing the young piglets from the sow when 3 days old is now largely discarded. There is general agreement that it is advantageous to allow them to suckle for at least 2 or perhaps 3 weeks after birth. Earlier weaning than this involves a lot of attention and labour, since the piglets have to be frequently fed and the greatest care is necessary to keep the troughs and utensils sterilized to prevent digestive upsets and scouring, due to bacterial contamination. Another disadvantage of too-early weaning is that artificial heating is essential and the piglets have to be kept in draught-proof quarters.

By weaning at 2 to 3 weeks the piglets can be placed immediately on dry food, provided there is access to plenty of clean drinking water. The dry meal is first introduced at about 5 days of age, when the piglets are still on the sow, since this prevents too drastic a change of diet at weaning. In a short time the meal can be fed in the form of pellets which is both economical and enables the troughs to be kept clean without difficulty. It is undesirable to provide the pigs with milk or gruel. Results from liquid milk substitutes have been disappointing owing to the difficulty of keeping the equipment clean, especially where fat-containing feeds are given, and most workers agree that mortality tends to be high and scouring prevalent so that the pigs suffer a let-back. The best method of weaning is to remove the sow from the litter and supply dry food at which the piglets will generally start nibbling after 24 hours' starvation.

It will be realized that the nutritional requirements of pigs change rapidly at this early age. For pigs weaned at 2 or 3 days, after they have benefited from the sow's colostrum, synthetic milk products, based on the composition of sows' milk, and made up from complex proprietary mixtures, are available. They are all based on a high percentage of dried skim milk with smaller amounts of other nutrients such as emulsified fat (lard), casein, glucose, dried egg and yeast. All the necessary minerals, including trace elements, as well as the essential vitamins are included. The mixture also includes one if not two antibiotics, which are most beneficial at this stage, and these are included in the correct proportions. The powder contains at least 25 to 30 per cent of protein and can be mixed with water to give liquid about 19 per cent solids which is of milk-like consistency. Access to fresh water is also permitted. It is of interest to note that 2-day-old pigs cannot utilize sucrose or cane sugar and death usually follows 4 days of sucrose feeding. This disability only lasts a week or ten days and is possibly due to the absence of the necessary enzyme to break down the sucrose before it can be absorbed. After about 4 weeks the digestive enzymes of the baby pig can deal better with sucrose than with lactose. Pigs can be brought on to solid food at about 5 days of age.

When pigs are weaned at 2 or 3 weeks, or when weighing about 10 lb, they can be placed immediately on pig-starter meals or pellets.

Examples of such diets, as worked out at the Rowett Research Institute, are as follows:

	<i>Mixture A</i> <i>per cent</i>	<i>Mixture B</i> <i>per cent</i>
Roller-dried skim milk	42	—
White fish meal	15	32
Rolled oat groats	22	47
Sugar (sucrose)	10	10
Dried yeast (75 per cent unextracted)	5	5
Cod liver oil	2	2
Salt (NaCl)	0.5	0.5
Auroface 2A*	2.5	2.5
Special trace mineral supplement .	1	1

Typical analyses of such diets on the air-dry basis are as follows:

	<i>Mixture A</i> <i>per cent</i>	<i>Mixture B</i> <i>per cent</i>
Dry matter	92.6	91.9
Crude protein	29.2	28.1
Crude fibre	0.3	0.4
Crude fat	3.7	6.4
Total ash	8.0	8.1
Calcium (as CaO)	2.4	3.1
Phosphorus (as P ₂ O ₅)	2.5	3.0

At the prices prevailing in October, 1958, Mixture B containing no dry skim milk was appreciably the cheaper.

The meal or pellets are fed to appetite and drinking water is provided separately in unlimited amount. A good state of health is maintained and liveweight gains are generally better than on the sow. The smaller piglets generally make much better gains so that the litters are more uniform. There is a difference of opinion on the optimum weaning weight to aim at since some consider that forcing the pigs to show exaggerated growth is harmful in that they have less stamina and utilize their feed less effectively. Perhaps it is better to aim at a weaning weight no higher than that considered normal when the piglets are raised by the sow. It should also be pointed out that when the piglets weigh about 25 lb the protein supply can be cut down by about 20 per cent without affecting the rate of growth. If the nursing period is made very short the cost of the special feed is high since it contains more of the expensive ingredients. This is off-set to some extent by the saving of meal fed to the suckling sow.

Work is still proceeding on the economic aspects of this system. Many feeders consider it more economical to rear pigs on the sow until 20–25 lb in live weight.

TYPICAL RATIONS

Typical rations fed to pigs for maintenance and various productive purposes at different stages of growth and fattening are given below.

A. In-pig sows and gilts

	<i>lb</i>
Barley meal	49
Weatings	20
Finely-ground oats	25
White fish meal	5
Minerals	1
	100
Digestible crude protein =	11.6
T.D.N.	= 66.4

* Contains 3.6 g chlortetracycline hydrochloride/lb (Cyanamid of Great Britain Ltd.)

The white fish meal is increased gradually to 10-12 per cent about a fortnight before farrowing. No minerals are then necessary.

Many feeders include 10-15 per cent of bran in the ration, in replacement of ground oats, at farrowing time.

If ex. soya-bean meal or ex. dec. ground-nut meal is fed in replacement of white fish meal, the amount given should start at 10 per cent and increase to 15 per cent before farrowing and 2 per cent of mineral mixture should also be included in the diet.

If the sows are indoors or in yards, some green foods should also be given.

Creep-feed (3 to 8 weeks of age; most economically fed in the form of pellets)

	lb
Barley meal	33
Weatings	20
Flaked maize	30
White fish meal (finely ground)	10
Dried separated milk	5
*Vitamin pre-mix	1
Minerals	1
	100
Dig. Protein =	15.4
T.D.N. . =	73.0

Lactating sow and weaner

	lb
Barley meal	45
Weatings	30
Flaked maize	15
White fish meal	5
Meat and bone meal	5
	100
Dig. Crude protein =	13.6
T.D.N. . . =	71.0

Bacon pigs

	Weaning to 90 lb liveweight				90 to 120 lb liveweight			Fattening	
	lb	lb	lb	lb	lb	lb	lb	lb	lb
White fish meal	7	—	—	4	4	—	—	—	—
Meat and bone meal	—	10	—	—	—	—	—	—	—
Ex. Soya-bean meal	—	—	15	—	—	6	—	—	—
Ex. Dec. ground-nut meal	—	—	—	6	—	—	6	—	—
Bean meal	10	—	—	10	—	—	—	10	—
Barley meal	54	47	40	50	51	59	54	65	75
Finely ground oats	25	—	—	—	20	—	—	—	—
Maize meal	—	20	20	—	20	15	15	—	—
Coarse middlings or weatings	—	20	20	25	—	15	20	20	20
Dried grass or lucerne meal	3	3	3	3	3	3	3	3	3
Minerals	1	—	2	2	2	2	2	2	2
	100	100	100	100	100	100	100	100	100
Dig. Crude protein	13.7	12.0	13.3	14.6	10.0	10.3	11.3	10.8	8.8
T.D.N.	66.5	70.3	69.0	66.4	68.4	68.8	68.4	66.7	67.3

Vitamin supplement should contain 800 units vitamin A and 200 units D3 per g.

1. For information on the mineral requirements see p. 15.
2. T.D.N. per 100 lb of flaked maize=86; barley meal 71; oats 62, ex. ground-nut meal 73.
3. Some feeders include 5 per cent of ex. dec. ground-nut meal or 5 per cent ex. soya-bean meal in the fattening ration to improve the T.D.N. content.
4. For information on the feeding of antibiotics to pigs see p. 24.
5. Many feeders will prefer to feed the weaners' diet to 120 lb instead of 90 lb live weight, and follow with fattening ration.

Tables of Feedingstuffs

NOTES ON THEIR MAKE-UP AND USE

In this edition a revision of the lay-out of the Tables of composition and nutritive value of the feedingstuffs has been undertaken. One fundamental change has been to separate the data on the nutritive aspects of foods obtained from digestion trials with ruminants (usually wether sheep) from the more limited data obtained with trials on pigs. The expression of the nutritive value of foods in terms of starch and protein equivalents applies strictly to ruminant animals only, and it has been decided to keep all these data together and to provide a separate section for the data obtained with digestibility trials on pigs, expressing the nutritive values of foods so obtained in terms of Total Digestible Nutrients.

In the Ruminants Section the tables of chemical composition now include a column for "true protein" values, obtained by standard copper-precipitating techniques. Under the group heading of "Digestible Nutrients" the former column of "Digestible True Protein" has been omitted, since this has always been a calculated rather than determined value, derived from chemical analysis of the food. (The nature of the faeces of an animal precludes a valid determination of digestible true protein). Also omitted in this edition is the column of nutritive ratios (which have a very limited applicability and usefulness). An addition to this section is a column for protein equivalents calculated conventionally according to the method given in the text. An exception is, however, made in the case of Silage, where owing to normal breakdown of much of the protein during the fermentation processes it is preferable to evaluate the protein fractions in terms of digestible crude protein. It is hoped that users of these tables will find the adjacent placing of the figures for starch equivalent and protein equivalent of greater convenience when working out rations. The figures for the "V" numbers for foods are included only where they are actually used in the computation of starch equivalents; where calculations are based on fibre-correction factors there is no justification for including "V" numbers.

One disadvantage of quoting a single set of figures for the composition and nutritive value of a particular type of feedingstuff is that of implying constant make-up and worth. It must be appreciated that all feedingstuffs are variable in both composition and nutritive value. In many instances there have been too few determinations made, especially of digestible data.

be able confidently to assert that the values quoted are "average" and the "typical" (in a very guarded sense) is preferable. The fact that a set of values is quoted in no sense implies that these are absolute; in many instances their exact origin is unknown, and the best that can be hoped for is that they are reasonably representative.

An attempt has been made to rationalize some of the older data by reclassifying them to "standard" moisture contents. With some feedingstuffs, such as meadow hays that exhibit a wide range of composition and nutritive value a complete reclassification has been attempted to cover broadly this range. For this purpose the very extensive laboratory records of nutrition chemists of the National Agricultural Advisory Service have been freely drawn upon, since these data are far more representative of the qualities of feeds found on farms today than some of the older figures.

A re-examination has also been made of the composition of some present-day qualities of oil-seed cakes with consequent minor modifications of some of the figures that have appeared in earlier editions of this Bulletin. The data for Artificially Dried Green Fodder Crops and for Feedingstuffs of Animal Origin have been assembled into separate sections to facilitate reference.

NOTE

There may be a slight discrepancy in some instances between the figures given in the tables for the compositions of a feedingstuff and those used to illustrate the computation of rations in the text.

It is important that the stockfeeder should realize that the composition of a feedingstuff may vary with:

- (a) the source of supply, particularly if imported
- (b) the method of milling or manufacture, and
- (c) the actual moisture content.

Home-grown barley may vary in protein content from 6.25 in a good malting sample to 11.5 per cent in the best feeding barley. To give a mean protein content for barley of 8 per cent is not very informative. The greatest source of error in computing rations is, however, in the wide variation in the dry matter content of feeds. Thus after a wet harvest cereals may contain 18 per cent of moisture when milled whereas the feeder customarily computes his rations on the assumption that moisture will only amount to 13 or at the most 15 per cent. This will have a serious effect on the food-conversion factors.

The danger of serious error can be lessened if the feeder:

- (a) uses a variety of feeds and is not too dependent on one feed ingredient
- (b) checks the dry matter content of his feeds by having a periodical determination carried out by the N.A.A.S.
- (c) adjusts his rations by keeping a careful check on productivity and the conditions of his animals.

Composition and Nutritive Value of Feedingstuffs

	Composition per cent as shown by chemical analysis						Digestible nutrients per cent				Calculated from digestible nutrients			
	Dry Matter (1)	Crude Protein (2)	Oil (Ether Extract) (3)	Crude Fibre (4)	Carbohydrate (Nitrogen-free Extractives) (5)	Ash (6)	True Protein (7)	Dig. Crude Protein (8)	Dig. Oil (Dig. Ether Extract) (9)	Dig. Fibre (10)	Dig. Carbohydrate (Dig. Nitrogen-free Extractives) (11)	V. (12)	Per 100 lb	
													Starch Equivalent (13)	Protein Equivalent (14)
1. ROOTS														
Artichoke, Jerusalem	20.4	1.5	0.2	0.7	16.9	1.1	0.9	1.0	—	0.2	15.8	92	16.4	0.7
Carrots	13.0	1.2	0.2	1.4	9.3	0.9	0.8	0.8	0.1	0.7	8.9	87	8.8	0.6
Fodder beet (Hunsballe X)*	22.2	1.0	0.1	1.1	18.8	1.2								
Fodder beet (Pajbjerg)	21.5	1.1	0.2	1.3	17.9	1.0	1.6	0.7		0.6	7.4	90	8.3	0.5
Kohlrabi	12.7	2.0	0.1	1.4	8.2	1.0	0.4	0.7		0.3	7.5	70	5.5	0.4
Mangolds, white-fleshed globe	10.7	1.0	0.1	0.7	8.2	0.7	0.4	0.7		0.3	8.5	70	6.2	0.4
Mangolds, intermediate	12.0	1.0	0.1	0.7	9.4	0.8	0.4	0.7		0.3	9.4	70	6.8	0.4
Mangolds, yellow-fleshed globe or tankard	13.2	1.2	0.1	0.8	10.2	0.9	0.6	0.7		0.3	9.5	70	6.8	0.4
Mangolds long red	13.1	1.0	0.1	0.8	10.3	0.9	0.4	0.7	0.1	0.7	10.9	86	10.6	0.8
Parsnips	15.0	1.3	0.3	1.2	11.3	0.9	0.9	1.0		—	17.7	100	18.5	0.8
Potatoes	23.8	2.1	0.1	0.9	19.7	1.0	1.6	1.1		0.4	19.3	75	15.0	0.5
Sugar beet	23.4	1.1	0.1	1.1	20.4	0.7	0.6	0.8		0.8	7.5	85	7.3	0.7
Swede turnip	11.5	1.3	0.2	1.2	8.1	0.7	0.5	1.1		0.3	5.2	77	4.4	0.4
Turnip	8.5	1.0	0.2	0.9	5.7	0.7	0.6	0.6						
2. LEAVES OF ROOTS														
Artichoke tops	32.3	3.4	1.1	5.4	17.4	5.0	3.1	2.0	0.5	2.2	13.1		16.2	1.8

* The dry matter content of fodder beet as with other root crops is subject to fairly wide variation say within the range of about 15 to 25 per cent.

	18.2	3.4	0.9	2.5	7.1	4.3	2.7	2.2	0.5	1.4	4.7	7.7	1.3
Carrot leaves													
Fodder beet tops (Hunsballe)	18.2	3.4	0.9	2.5	7.1	4.3	2.7	2.2	0.5	1.4	4.7	7.7	1.3
Fodder beet tops (Pajbjerg)	20.2	2.7	0.4	2.0	10.0	5.1							
Fodder beet tops (Pajbjerg)	16.8	1.8	0.3	1.4	7.5	5.8							
Kohlrabi leaves	13.5	2.8	0.4	1.6	7.1	1.6	1.3	1.9	0.2	0.9	5.7	6.8	1.1
Mangold leaves	11.0	2.4	0.4	1.6	4.6	2.0	1.8	1.6	0.2	0.9	3.5	5.3	1.3
Potato haulm	23.0	2.5	1.0	6.2	10.2	3.1	2.0	1.1	0.2	2.2	6.1	7.2	0.8
Sugar beet tops	16.2	2.0	0.5	1.6	8.7	3.4	1.5	1.4	0.3	1.1	7.2	8.6	1.1
Sugar beet tops, dried (high ash)	92.9	7.7	1.1	6.4	30.0	47.7							
Sugar beet tops, dried (medium ash)	86.7	10.0	1.7	8.9	45.5	20.6							
Sugar beet tops, dried (low ash)	90.4	10.4	1.2	11.0	56.1	11.7							
Turnip leaves	11.6	2.2	0.5	1.5	5.3	2.1	1.1	1.5	0.2	0.8	4.2	5.3	0.9
3. OTHER GREEN FOODS													
Cabbage, drumhead	11.0	1.5	0.4	2.0	5.9	1.2	1.1	1.1	0.2	1.4	4.6	6.6	0.9
Cabbage, open leaved	15.3	2.5	0.7	2.4	8.1	1.6	1.9	1.8	0.4	1.7	6.5	9.5	1.5
Chickweed	9.2	1.7	0.2	1.1	2.9	3.3	1.9	1.5	0.2	0.8	3.7	5.2	1.2
Comfrey	11.5	2.5	0.3	1.7	5.0	2.0							
Comfrey (Russian)	12.4	3.4	0.3	1.5	4.9	2.3							
Kale, thousandhead	16.0	2.2	0.4	3.2	8.5	1.7	1.7	1.7	0.2	1.8	7.6	10.0	1.5
Kale, marrowstem (unthinned)	14.0	2.2	0.5	2.5	6.9	1.9	1.6	1.7	0.3	1.6	6.1	9.1	1.4
Kale, marrowstem (singled-out)	14.0	2.1	0.3	2.5	7.3	1.8	1.5	1.6	0.2	1.5	6.5	9.0	1.3
Kale, marrowstem (dried)	88.0	13.3	2.1	15.1	48.4	9.1							
Purple sprouting broccoli	12.3	1.9	0.3	1.5	7.4	1.2	1.2	1.4	0.2	1.1	5.9	7.5	1.0
Mustard	15.0	2.9	0.4	2.9	7.4	1.4	2.3	1.9	0.2	1.5	5.0	7.2	1.6
Rape	14.0	2.8	0.8	3.5	5.6	1.3	2.1	2.0	0.5	1.9	3.8	6.9	1.6
4. CEREALS													
Barley in flower	31.4	2.2	0.5	9.9	16.8	2.0	2.0	1.5	0.3	6.4	12.1	16.0	1.4
Maize	19.4	1.7	0.5	5.6	10.4	1.2	1.3	1.0	0.3	3.1	6.7	9.1	0.8
Millet	13.0	1.3	0.2	4.1	6.2	1.2	1.0	0.7	0.1	2.2	3.8	5.4	0.5
Oats in flower	23.2	1.9	0.6	8.5	10.4	1.8	1.7	1.4	0.4	4.9	6.5	10.0	1.3
Rye	23.4	3.0	0.9	7.5	10.3	1.7	2.3	2.1	0.5	4.9	7.0	11.3	1.7

Sweet clover	20.0	3.2	0.0	4.8	9.4	2.0	3.5	2.8	0.5	2.6	4.7	8.8	2.3
Trifolium (see Crimson clover)													
White clover, beginning to flower	18.5	4.4	0.8	4.3	6.9	2.1	3.5	2.8	0.5	2.6	4.7	8.8	2.3
Beans, beginning to flower	15.0	3.2	0.8	3.3	5.7	2.0	2.4	2.3	0.5	1.6	4.1	7.1	1.9
Kidney vetch	18.0	2.4	0.6	5.1	8.6	1.3	1.6	1.4	0.3	2.7	5.7	7.9	1.0
Lucerne (in early flower)	24.0	4.1	0.4	7.2	9.9	2.4	3.0	3.1	0.1	3.2	6.6	10.3	2.5
Lucerne (in bud)	22.0	4.5	0.5	6.2	9.0	1.8	3.3	3.6	0.1	3.1	6.8	11.3	3.0
Lucerne (before bud)	15.0	3.8	0.4	3.3	5.7	1.8	2.7	3.2	0.1	2.1	4.6	9.0	2.6
Peas, beginning to flower	16.8	3.5	0.6	5.9	5.6	1.2	2.7	2.4	0.3	3.0	3.7	6.8	2.0
Sainfoin, early flower	22.5	4.4	0.6	4.7	11.4	1.4	3.7	3.2	0.4	2.1	8.9	13.1	2.8
Sainfoin, full flower	25.0	4.4	0.6	5.9	12.5	1.6	3.9	2.9	0.3	2.7	7.6	11.6	2.6
Trefoil	20.0	3.5	0.8	5.7	8.4	1.6	2.7	2.4	0.4	2.8	5.9	9.1	2.0
Vetches, in flower	17.5	3.2	0.5	5.1	7.2	1.5	2.4	2.2	0.3	2.3	4.9	7.5	1.8
Vetches, early growth	17.5	3.4	1.1	3.5	7.3	2.2	2.7	2.4	0.4	2.8	5.9	9.1	2.0
Vetches (full flower) with oats	29.0	3.0	0.9	8.1	14.7	2.3	2.4	2.2	0.3	2.3	4.9	7.5	1.8
7. MISCELLANEOUS													
Brushwood	75.0	4.6	1.9	26.7	40.3	1.5	4.1	2.1	0.8	6.7	20.2	14.8	1.8
Buckwheat	16.3	2.5	0.6	4.3	7.8	1.1	2.0	1.6	0.3	2.5	5.2	8.1	1.3
Dandelion	14.5	2.8	0.7	1.5	7.5	2.0	4.6	2.2	0.5	9.6	10.9	8.9	1.8
Gorse	51.3	5.3	1.1	24.0	18.1	2.8	2.8	1.4	1.5	7.0	8.6	6.0	1.0
Heather	50.0	3.5	4.3	22.7	16.6	2.9	4.6	2.8	0.5	9.6	10.9	8.9	1.8
Heather (dried tips)	92.7	5.2	5.2	34.3	44.6	3.4	11.2	7.6	1.1	4.1	33.6	37.3	6.8
Artichoke tops (dried)	87.5	12.7	2.2	14.2	48.1	10.3	11.2	7.6	1.1	4.1	33.6	37.3	6.8
Ash leaves (dried)	88.0	10.1	2.3	8.9	59.0	7.7	11.2	7.6	1.1	4.1	33.6	37.3	6.8
Beech leaves (dried)	84.6	5.6	3.1	25.2	47.0	3.8	12.8	11.6	0.7	4.9	40.7	50.0	10.0
Elm leaves (dried)	88.0	15.9	2.9	8.6	49.9	10.7	12.8	11.6	0.7	4.9	40.7	50.0	10.0
Hop leaves and bine (dried)	89.4	12.5	3.5	24.5	38.1	10.8	10.6	8.0	2.5	7.6	27.1	31.1	7.0
Horse chestnut leaves (dried)	87.9	14.7	2.0	14.9	48.5	7.8	8.0	6.2	2.4	5.3	32.5	37.6	4.9
Leaves of trees in July (dried)	84.0	10.5	3.0	14.2	49.3	7.0	14.8	12.8	4.9	6.0	30.0	46.5	11.0
Nettles (dried)	88.6	18.3	7.7	10.6	38.0	14.0	14.8	12.8	4.9	6.0	30.0	46.5	11.0
Oak leaves (dried)	85.2	14.8	3.8	20.6	41.9	4.1	8.2	6.0	6.9	5.6	26.2	33.9	4.7
Poplar leaves in October (dried)	84.0	10.8	8.7	17.4	39.6	7.5	8.2	6.0	6.9	5.6	26.2	33.9	4.7
Willow leaves (dried)	89.5	15.3	5.4	19.5	40.4	8.9	8.2	6.0	6.9	5.6	26.2	33.9	4.7

Composition and Nutritive Value of Feedingstuffs—continued

	Composition per cent as shown by chemical analysis							Digestible nutrients per cent				Calculated from digestible nutrients		
	Dry Matter (1)	Crude Protein (2)	Oil (Ether Extract) (3)	Crude Fibre (4)	Carbohydrate (Nitrogen-free Extractives) (5)	Ash (6)	True Protein (7)	Dig. Crude Protein (8)	Dig. Oil (Dig. Ether Extract) (9)	Dig. Fibre (10)	Dig. Carbohydrate (Dig. Nitrogen-free Extractives) (11)	V. (12)	Per 100 lb	
													Starch Equivalent (13)	Protein Equivalent (14)
8. SILAGE														
Alsike	25.0	3.4	1.8	6.8	10.9	2.1	2.7	2.0	1.2	3.4	6.2		10.7	See digestible crude protein figure
Clover, red	20.0	4.1	1.1	6.0	6.5	2.3	2.9	2.7	0.6	3.2	4.7		8.5	
Grass (first quality)	20.0	3.6	1.0	4.1	9.3	2.0	2.0	2.6	0.6	2.9	7.0		12.2	
Grass (second quality)	22.5	3.2	0.8	6.1	10.4	2.0	1.8	2.2	0.5	4.0	6.8		11.6	
Grass (hay maturity)	25.0	2.6	1.0	8.4	10.5	2.5	1.8	1.8	0.5	4.9	6.1		10.2	
Lucerne	25.0	4.2	2.1	7.4	8.8	2.5	3.1	2.8	1.0	3.1	6.1		11.1	
Maize	20.0	1.7	0.9	6.2	9.7	1.5	1.3	0.9	0.4	3.5	6.7		9.3	
Maize, Jaune Gros, English grown	20.0	2.2	1.1	4.7	10.8	1.2	1.3	1.4	1.0	3.2	7.5		12.1	
Mangold leaves	20.0	2.7	1.0	2.9	8.9	4.5	1.5	1.8	0.4	1.6	4.8		7.0	
Marrowstem kale	20.0	2.5	0.6	4.7	9.1	3.1	1.9	1.9	—	3.5	7.7		11.6	
Mustard	20.0	3.3	0.5	5.0	8.1	3.1	2.6	2.1	0.5	2.5	6.9		10.6	
Oats, green	25.0	2.0	0.8	9.0	11.3	1.9	1.5	1.2	0.4	5.4	6.2		9.4	
Overheated ryegrass and clover	32.0	4.3	1.1	10.2	13.5	2.9	4.3	0.5	0.8	5.6	7.6		10.5	
Pea haulms and pods } Canning	25.0	3.7	1.5	6.4	9.1	4.3	1.8	2.1	1.4	3.6	6.3		12.3	
Pea pods } Industry	27.5	3.5	1.0	8.4	12.8	1.8	1.6	2.3	0.9	5.5	9.8		15.9	
Potatoes	25.0	2.1	0.5	0.7	20.4	1.3	1.2	1.0	0.1	—	17.3		17.5	
Potato haulms	25.0	3.2	2.7	4.4	9.1	5.6	2.3	1.2	1.2	1.7	5.0		8.0	
Rye	20.0	2.4	0.8	6.7	8.7	1.4	1.8	1.4	0.3	4.0	5.2		8.4	
Sainfoin	25.0	4.5	1.6	8.8	8.5	—	—	—	—	—	—		—	

	12.0	1.0	0.2	2.4	7.5	0.9	0.8	0.5	0.1	1.2	5.6	6.7
Sugar beet pulp, wet	.	.	.	.	7.5	0.9	0.8	0.5	0.1	1.2	5.6	6.7
Sugar beet tops	20.0	2.1	0.6	3.0	7.9	6.4	1.0	1.3	0.3	2.2	6.3	8.3
Sugar beet tops plus wet sugar beet pulp	16.0	2.4	0.6	2.1	8.9	2.0	1.5	1.6	0.4	1.7	7.6	10.4
Sunflowers	20.0	1.9	0.9	6.1	9.0	2.1	—	1.0	0.6	3.0	5.9	8.8
Turnip tops	17.5	2.1	0.6	2.8	6.3	5.7	1.1	1.5	0.5	1.9	5.2	8.6
Vetch and oats	25.0	3.1	1.1	7.3	11.5	2.0	2.1	2.0	0.8	4.2	8.0	11.7
9. HAY												
Barley (just past milk stage)	85.0	6.9	1.9	24.6	45.3	6.3	—	4.6	0.8	15.2	28.6	42.2
Clover, crimson	85.0	12.2	2.5	26.7	36.2	7.4	9.4	8.5	1.0	12.6	23.6	33.6
Clover, red, poor	85.0	11.1	2.1	28.9	37.8	5.1	9.4	5.7	1.0	11.6	24.6	30.1
Clover, red, good	85.0	13.7	3.0	24.4	37.8	6.1	10.7	8.7	1.7	11.5	26.5	38.9
Clover, red, very good	85.0	15.6	3.3	22.6	36.4	7.1	11.8	10.9	2.1	11.2	27.3	43.3
Clover, red, damaged	85.0	12.0	1.5	33.5	30.9	7.1	10.7	6.2	0.7	13.4	18.5	22.1
Couch grass	85.0	7.6	1.1	15.1	56.6	4.6	—	—	—	—	—	—
Lucerne, before flowering	85.0	16.4	2.4	27.3	31.5	7.4	12.4	12.2	1.1	11.4	21.4	32.4
Lucerne, in full flower	85.0	14.5	2.6	30.0	29.7	8.2	10.9	9.9	1.2	13.4	18.4	27.5
Lucerne, in half flower (very good quality)	85.0	19.1	1.1	25.7	34.0	8.1	15.0	14.1	—	12.3	20.6	37.4
Meadow hay (excellent)	85.0	13.7	3.0	19.5	41.0	7.8	10.9	9.3	1.5	12.9	30.4	49
Meadow hay (very good)	85.0	10.5	3.4	22.0	41.5	7.6	9.0	6.3	1.7	13.2	27.3	42
Meadow hay (good)	85.0	8.5	2.5	25.5	41.7	6.8	7.1	4.8	1.3	14.0	25.0	36
Meadow hay (medium)	85.0	8.2	2.0	28.1	40.1	6.6	7.2	4.1	1.0	15.5	22.9	32
Meadow hay (poor)	85.0	7.6	1.6	30.4	38.9	6.5	6.7	3.4	0.7	15.2	21.4	27
Meadow hay (very poor)	85.0	6.4	1.5	33.0	38.3	5.8	5.5	2.9	0.6	15.5	19.2	22
Millet hay	85.0	10.6	2.2	28.8	37.8	5.6	9.3	6.0	0.9	17.3	23.0	35
Mineral-deficient hay (mainly purple molinia and brown bent)	85.0	11.0	1.9	29.2	39.9	3.0	10.8	5.4	0.2	16.2	15.5	24
Oats (milk stage)	85.0	8.0	2.6	27.5	40.2	6.7	—	4.4	1.6	14.3	22.6	33
Reed hay	85.0	8.1	1.1	27.4	40.8	7.6	—	—	—	—	—	—
Rice grass, poor	85.0	6.7	1.4	26.0	42.4	8.5	6.5	2.6	0.5	16.3	20.6	30
Rye, before flowering	85.0	10.3	2.5	28.2	38.7	5.3	9.2	7.2	1.5	17.0	27.1	43
Rye, in flower	85.0	6.2	2.0	34.0	38.2	4.6	—	—	—	—	—	—
Ryegrass, perennial	85.0	10.3	2.6	25.1	40.6	6.4	9.0	6.3	1.1	13.0	26.0	38
Ryegrass, Italian	85.0	11.1	3.5	21.8	41.1	7.5	9.7	6.8	1.7	12.6	27.6	43

Composition and Nutritive Value of Feedingstuffs—continued

	Composition per cent as shown by chemical analysis							Digestible nutrients per cent				V. (12)	Calculated from digestible nutrients	
	Dry Matter (1)	Crude Protein (2)	Oil (Ether Extract) (3)	Crude Fibre (4)	Carbohydrate (Nitrogen-free Extractives) (5)	Ash (6)	True Protein (7)	Dig. Crude Protein (8)	Dig. Oil (Dig. Ether Extract) (9)	Dig. Fibre (10)	Dig. Carbohydrate (Dig. Nitrogen-free Extractives) (11)		Starch Equivalent (13)	Protein Equivalent (14)
9. HAY contd														
Sainfoin, before flowering	85.0	15.5	3.2	25.2	34.3	6.8	12.4	11.0	2.1	10.8	25.4	40	9.4	
Sainfoin, in flower	85.0	13.4	2.6	28.5	33.1	7.4	11.3	9.8	1.6	12.0	25.8	38	8.7	
Timothy	85.0	8.4	2.4	28.2	40.8	5.2	7.6	4.0	1.0	15.0	25.3	35	3.6	
Trefoil	85.0	15.6	3.4	24.8	33.6	7.6	12.3	11.9	1.6	10.9	23.5	37	10.2	
Seeds, hay (ryegrass and clover)	85.0	11.9	2.8	27.2	36.9	6.2	9.3	6.1	1.2	13.0	21.7	30	4.8	
Seeds hay, good quality	85.0	13.0	2.3	23.1	37.8	8.8	11.5	7.8	1.3	13.0	25.5	40	7.0	
Vetches, beginning to flower	85.0	20.2	2.3	23.9	29.1	9.5	15.8	15.4	1.4	12.9	18.9	37	13.2	
Vetches, in full flower	85.0	14.5	2.5	26.0	33.5	8.5	11.6	9.6	1.5	13.0	20.1	33	8.1	
Vetches and oats (vetches in flower)	85.0	11.7	3.3	24.5	36.8	8.7	9.4	6.6	1.7	12.4	23.6	34	5.4	
Wheat (milk stage)	85.0	5.6	1.6	24.9	46.8	6.1	—	3.1	0.9	14.5	29.0	40	3.1	
10. DRIED GRASSES AND LEGUMES														
Grass dried (very leafy)	90.0	18.7	3.0	17.7	40.6	10.0	17.6	14.1	1.7	13.3	30.5	54.1	13.6	
Grass dried (leafy)	90.0	15.0	2.6	20.9	40.7	10.8	13.6	10.0	1.5	15.9	31.0	51.7	9.3	
Grass dried little stem, early flowering stage	90.0	12.1	2.2	24.4	42.3	9.0	11.4	7.3	1.1	18.8	31.4	51.2	6.8	
Grass dried stemmy, flowering stage	90.0	10.4	2.2	24.4	42.7	10.3	9.7	5.8	1.2	18.6	30.9	49.5	5.5	
American crimson clover, dried in pre-flower	90.0	18.1	2.7	18.6	38.6	12.0								
American crimson clover, dried in early flower	80.0	15.9	3.0	25.2	35.2	10.7								

Ladino clover, dried in early flower . . .
 Lucerne meal, English (from crop just into flower bud) . . .
 Lucerne meal, English (from crop in early flower) . . .
 Lucerne leaf meal, American . . .
 Strawberry clover, dried in early flower . . .
 Bird's foot trefoil, dried in mid-August. . .

II. STRAWS

Barley straw, spring	86.0	3.3	1.8	33.9	42.4	4.6	3.1	0.8	0.6	18.3	22.5	23	0.7
Barley awns*	86.0	4.8	1.8	21.9	46.1	11.4							
Barley cavings	86.0	4.4	1.9	33.1	41.3	5.3							
Bean straw (including pods)	86.0	4.5	0.8	43.1	33.0	4.6	3.6	2.2	0.5	18.7	22.0	19	1.7
Bean stems and leaves	86.0	4.4	0.8	42.4	35.0	3.4							
Bean cavings	86.0	7.6	1.1	36.2	34.8	6.3							
Bean pods	86.0	7.7	0.9	28.5	42.6	6.3							
Buckwheat straw	86.0	4.9	1.2	39.1	35.5	5.3	4.4	2.3	0.5	17.6	18.4	16.4	1.9
Buckwheat husks	86.0	4.5	1.1	43.1	35.1	2.2							
Clover straw (red)	84.0	9.1	1.8	44.6	22.8	5.7	8.2	4.0	0.6	16.4	11.1	7	3.5
Flax stems minus leaves	88.4	2.3	0.6	62.8	21.4	1.3							
Lentil pods	85.0	18.4	1.8	19.5	37.4	7.9							
Linseed chaff (see also Flax by-products)	88.0	3.5	3.4	40.5	34.8	5.8	3.1	1.4	1.7	12.1	12.9	17.9	1.2
Lupin pods	87.3	9.0	0.7	29.2	42.4	6.0							
Maize, stripped stalks	87.8	2.9	0.8	36.9	45.3	1.9							
Millet, chaff and husks	88.0	4.8	2.2	40.8	29.0	11.2	4.3	1.7	0.7	15.1	13.6	19.3	1.4
Oat straw, spring	86.0	2.9	1.9	33.9	42.4	4.9	2.7	1.0	0.6	18.3	19.4	20	0.9
Oat chaff (glumes) spring*	86.0	6.0	2.1	22.8	44.8	10.3	5.5	2.2	1.0	10.2	21.9	29	1.9
Oat cavings, spring	86.0	4.4	2.2	30.9	42.0	6.5							
Oat straw, winter	86.0	1.9	1.5	34.6	43.1	4.9	1.7	0.6	0.5	19.7	19.8	21	0.5
Oat chaff (glumes), winter*	86.0	4.9	1.9	24.1	46.3	8.8							

* Glume meal is made by grinding wheat chaff, oat chaff or barley awns in a hammer mill. These chaffs often contain light or broken cereal grains, weed seeds and, with under-sown crops, a proportion of green leafy matter. Such glume meals are therefore distinctly richer in protein and starch equivalent than the pure chaffs, and may be used to replace part of the meadow hay in the maintenance rations of cattle. Grinding averts the risk of the weed seeds getting back to the land in the farmyard manure.

Composition and Nutritive Value of Feedingstuffs—continued

	Composition per cent as shown by chemical analysis						Digestible nutrients per cent				Calculated from digestible nutrients			
	Dry Matter (1)	Crude Protein (2)	Oil (Ether Extract) (3)	Crude Fibre (4)	Carbohydrate (Nitrogen-free Extractives) (5)	Ash (6)	True Protein (7)	Dig. Crude Protein (8)	Dig. Oil (Dig. Ether Extract) (9)	Dig. Fibre (10)	Dig. Carbohydrate (Dig. Nitrogen-free Extractives) (11)	V. (12)	Starch Equivalent (13)	Protein Equivalent (14)
II. STRAWS contd														
Oat cavings, winter	86.0	3.2	2.3	29.3	45.3	5.9	8.1	4.3	0.7	13.6	18.4		16.9	3.8
Oat straw chaff, winter	85.0	3.8	2.3	32.6	40.7	5.6	1.4	1.8	0.5	14.0	20.4		15	1.2
Oat straw chaff, fermented	84.1	3.6	3.4	32.4	39.0	5.7	3.5	0.4	0.9	0.4	11.5		3	0.2
Pea haulm	86.0	9.2	1.6	33.4	36.0	5.8	3.0	0.6	0.8	17.3	17.0		15	0.5
Pea cavings	86.0	11.7	2.4	28.0	35.8	8.1	2.9	0.6	0.7	20.4	15.3		14	0.5
Pea straw	86.0	9.0	1.6	35.3	33.5	6.6	3.1	1.1	0.4	22.1	11.3		22	0.9
Rape straw	84.0	2.5	1.2	37.8	38.7	3.8	8.1	4.3	0.7	13.6	18.4		16.9	3.8
Rice husks	90.0	3.8	1.4	37.9	32.8	14.1	1.4	1.8	0.5	14.0	20.4		15	1.2
Rye straw, spring	86.0	3.2	1.6	36.9	41.7	2.6	3.5	0.4	0.9	0.4	11.5		3	0.2
Rye straw, winter	86.0	3.1	1.4	40.0	37.6	3.9	3.0	0.6	0.8	17.3	17.0		15	0.5
Rye chaff	86.0	3.5	1.3	44.3	29.2	7.7	2.9	0.6	0.7	20.4	15.3		14	0.5
Soya bean pods	89.2	6.0	1.5	30.4	43.0	8.3	3.1	1.1	0.4	22.1	11.3		22	0.9
Soya bean straw	84.0	7.4	2.0	26.1	38.3	10.2	8.1	4.1	0.8	16.3	15.3		13	3.6
Tare or vetch straw	86.0	9.0	1.7	40.6	29.4	5.3	8.1	4.1	0.8	16.3	15.3		13	3.6
Tare or vetch pods	85.7	10.4	1.7	31.9	32.9	8.8	8.1	4.1	0.8	16.3	15.3		13	3.6
Timothy straw	91.9	2.2	1.2	38.7	46.5	3.3	—	0.1	0.4	18.0	14.7		13	0.1
Wheat straw, spring	86.0	2.9	1.3	35.9	39.8	6.1	—	0.1	0.4	18.0	14.7		13	0.1
Wheat cavings, spring	86.0	8.6	1.1	22.7	42.7	10.9	—	0.1	0.4	18.0	14.7		13	0.1
Wheat straw, winter	86.0	2.1	1.3	36.6	40.7	5.3	—	0.1	0.4	18.0	14.7		13	0.1

Composition and Nutritive Value of Feedingstuffs—continued

	Composition per cent as shown by chemical analysis							Digestible nutrients per cent				Calculated from digestible nutrients		
	Dry Matter (1)	Crude Protein (2)	Oil (Ether Extract) (3)	Crude Fibre (4)	Carbohydrate (Nitrogen-free Extractives) (5)	Ash (6)	True Protein (7)	Dig. Crude Protein (8)	Dig. Oil (Dig. Ether Extract) (9)	Dig. Fibre (10)	Dig. Carbohydrate (Dig. Nitrogen-free Extractives) (11)	V. (12)	Starch Equivalent (13)	Protein Equivalent (14)
12. GRAINS AND SEEDS, Oil Seeds contd														
Cottonseed, Brazilian	91.0	21.2	23.3	17.1	25.1	4.3	19.7	14.5	20.2	13.0	12.6	94	84.1	13.7
Ground-nuts, earth or pea-nuts	94.0	26.8	44.9	2.6	17.5	2.2	24.9	24.1	40.3	0.2	14.7	99	131.4	23.1
Hemp seed	91.0	18.2	32.6	15.0	21.0	4.2	17.3	13.7	29.3	9.0	16.8	96	104	13.2
Kapok seed	89.5	23.0	22.0	20.0	18.5	6.0	22.9	19.4	34.7	1.8	18.3	99	119	18.7
Linseed	93.0	24.2	36.5	5.5	23.0	3.8	22.9	19.4	34.7	3.5	22.6	99	144.2	7.9
Niger seed	95.0	23.0	38.0	16.0	13.0	5.0	8.3	8.0	46.7	1.5	14.5	99	130.8	14.9
Palm nut kernels	92.0	8.5	49.0	5.8	26.9	1.8	17.6	15.9	43.0	1.4	8.4	99	132.7	17.5
Poppy seed	92.8	20.9	32.5	8.6	23.3	7.5	18.8	18.3	44.6	1.7	20.8	98	78.9	27.8
Rape seed	93.0	19.7	45.1	5.9	18.1	4.2	12.6	12.9	30.9	9.5	10.4	92	96.5	12.0
Sesame seed	94.0	20.4	46.9	6.3	14.9	5.5	29.9	29.5	15.8	3.5	42.4	93	53.4	4.2
Shea nuts	94.5	7.5	49.0	2.9	32.0	3.1	10.3	8.5	1.9	3.5	42.4	93	53.4	4.2
Soya bean	90.0	33.2	17.5	4.1	30.5	4.7	2.8	2.7	1.9	4.1	32.6	95	41.2	2.4
Sunflower Seed	93.0	14.3	32.5	28.2	14.6	3.4	4.9	4.6	3.3	7.0	55.5	95	70.2	2.4
Miscellaneous Seeds														
Acorns, fresh	50.0	3.3	2.4	6.8	36.3	1.2	10.3	8.5	1.9	3.5	42.4	93	53.4	4.2
Acorns, dried	85.0	5.7	4.1	11.6	61.6	2.0	4.9	4.6	3.3	7.0	55.5	95	70.2	2.4
Buckwheat	86.0	11.3	2.6	14.4	54.9	2.8	10.3	8.5	1.9	3.5	42.4	93	53.4	4.2
Canary seed	70.0	15.2	5.8	4.5	48.5	2.8	10.3	8.5	1.9	3.5	42.4	93	53.4	4.2

Composition and Nutritive Value of Feedingstuffs—continued

	Composition per cent as shown by chemical analysis						Digestible nutrients per cent				Calculated from digestible nutrients			
	Dry Matter (1)	Crude Protein (2)	Oil (Ether Extract) (3)	Crude Fibre (4)	Carbohydrate (Nitrogen-free Extractives) (5)	Ash (6)	True Protein (7)	Dig. Crude Protein (8)	Dig. Oil (Dig. Ether Extract) (9)	Dig. Fibre (10)	Dig. Carbohydrate (Dig. Nitrogen-free Extractives) (11)	V. (12)	Starch Equivalent (13)	Protein Equivalent (14)
13. OIL CAKES AND MEALS contd														
Cotton cake, Bombay	88.0	20.3	4.8	21.8	35.3	5.8	19.5	15.6	4.5	4.4	19.0	84	40.1	15.2
Cotton cake, Brazilian	89.0	27.1	5.4	24.9	27.1	4.5	22.2	20.8	5.0	5.2	14.7	84	42.0	20.2
Cotton cake, Egyptian	88.0	23.2	5.0	21.3	32.7	5.8	22.2	17.8	4.6	4.5	17.7	84	41.6	17.3
Cotton cake, decorticated	90.0	41.1	8.0	7.8	26.4	6.7	39.6	35.3	7.5	2.2	17.7	97	68.3	34.5
Cotton cake, semi-decorticated	90.0	38.3	6.2	12.9	26.7	5.9	35.3	32.9	5.8	3.5	17.6	95	59.9	31.4
Grape-seed cake	88.5	12.0	7.5	38.9	25.5	4.6	42.5	40.5	5.4	0.5	22.4	98	69.7	39.0
Ground-nut cake, decorticated	90.0	45.4	6.0	6.5	26.4	5.7	29.4	27.8	8.2	2.6	18.5	86	57.0	27.3
Ground-nut cake, undecorticated	90.0	30.3	9.1	23.0	21.9	5.7	29.4	27.8	8.2	2.6	18.5	86	57.0	27.3
Ground-nut meal, decorticated extracted	90.0	49.7	0.7	7.9	26.0	5.7	45.7	44.2	0.6	0.6	22.1	98	60.6	42.2
Ground-nut meal, undecorticated extracted	92.0	31.6	1.9	25.2	29.0	4.3	30.8	29.1	1.5	2.9	19.9	84	44.2	28.7
Hemp seed cake	89.0	30.7	8.6	23.8	18.2	7.7	29.7	22.7	7.7	1.9	10.5	89	45.8	22.2
Hemp seed meal	88.0	34.7	1.7	25.6	16.7	9.3	32.7	26.1	1.3	2.1	8.9	86	31.4	25.1
Kapok cake	86.0	26.9	7.0	25.7	20.1	6.3	24.9	19.9	6.4	5.1	10.1	84	39.0	18.8
Linseed cake, English made	89.0	29.6	9.5	9.1	35.6	5.2	28.2	25.4	8.7	4.5	28.6	97	74.2	24.7
Linseed cake, foreign	90.0	31.9	6.9	9.4	36.2	5.6	27.7	27.4	6.4	4.7	29.0	97	68.7	25.3
Linseed meal, extracted	88.0	35.6	3.1	9.0	33.8	6.5	34.8	30.7	2.8	4.5	27.1	96	63.6	30.3
Media cake	89.0	31.8	10.4	20.8	18.4	7.6	29.8	22.1	8.3	4.1	11.1	86	46.2	21.1
Maize germ meal	89.0	13.0	12.5	4.1	55.8	3.6	12.8	10.4	11.5	2.5	46.9	97	84.2	10.3
Maize, flaked	80.0	0.8	4.2	1.5	72.5	8.8	6.1	8.8	1.5	2.5	46.9	97	84.2	10.3

14. FEEDING STUFFS OF ANIMAL ORIGIN													
Maize meal, degummed, cooked	88.0	18.0	7.5	17.5	40.0	5.0	29.8	25.9	4.7	4.9	19.7	89	51.4
Mustard seed cake	88.0	22.8	2.0	16.0	40.6	6.6	3.7	6.1	17.0	9.9	20.5	85	62.2
Mustard seed meal (extracted)	89.0	32.4	5.8	18.1	53.4	9.3	18.1	17.5	5.3	5.1	39.4	100	73.2
Niger cake	89.0	6.3	17.9	30.1	29.3	5.4	19.6	18.4	0.8	7.5	43.7	100	69.6
Olive cake	89.0	19.2	6.0	13.4	46.5	3.9	35.0	29.0	9.0	4.1	13.8	95	61.9
Palm kernel cake	90.0	20.4	0.9	15.0	49.7	4.0	30.7	29.3	7.6	0.7	20.4	95	59.2
Palm kernel meal, extracted	90.0	36.7	9.7	8.3	21.6	13.7	32.0	30.6	2.4	1.0	26.1	94	53.8
Poppy seed cake	94.4	45.2	24.2	8.2	8.3	8.5	3.4	40.1	10.7	1.4	11.7	97	73.3
Pumpkin seed cake	91.0	35.3	9.6	8.3	25.5	12.3	43.1	33.8	9.9	5.3	9.3	97	66.6
Rape cake	89.0	36.8	3.1	9.3	32.5	7.3	44.5	41.8	2.2	2.4	14.9	96	57.7
Rape meal, extracted	88.4	47.9	7.7	6.2	19.7	6.9	5.9	40.4	5.3	3.8	21.1	97	71.7
Safflower cake, decorticated	91.4	20.2	9.7	33.0	25.1	3.4	40.8	40.4	1.4	3.6	24.8	97	64.2
Safflower cake, undecorticated	91.0	44.7	11.9	4.5	21.0	8.9	34.3	33.4	12.1	3.6	14.5	95	72.2
Sesame cake, English	91.0	37.5	11.0	17.0	16.7	8.8	17.0	16.7	6.3	5.1	20.0	83	48.0
Sesame cake, French	94.0	46.4	2.4	7.7	26.7	10.8	34.9	34.3	0.9	4.9	20.0	95	53.5
Sesame meal, extracted	90.0	12.1	6.5	4.8	60.7	5.9	32.7	31.6	11.7	1.7	23.6	98	78.9
Shea nut cake	89.0	44.9	5.8	5.3	27.4	5.6	40.9	40.4	5.3	3.8	21.1	97	71.7
Soya bean cake	89.0	44.8	1.5	5.1	32.1	5.5	40.8	40.4	1.4	3.6	24.8	97	64.2
Soya bean meal, extracted	90.0	37.2	13.7	12.1	20.3	6.7	34.3	33.4	12.1	3.6	14.5	95	72.2
Sunflower cake, decorticated	90.0	18.5	7.2	29.1	28.0	7.2	17.0	16.7	6.3	5.1	20.0	83	48.0
Sunflower cake, undecorticated	90.0	38.1	1.0	16.3	28.1	6.5	34.9	34.3	0.9	4.9	20.0	95	53.5
Sunflower meal, extracted	87.0	35.2	12.3	6.7	27.7	5.1	32.7	31.6	11.7	1.7	23.6	98	78.9
Walnut cake	86.0	81.0	0.8	—	1.5	2.7	71.9	72.7	0.8	—	—	100	61.3
Blood meal	87.0	61.0	3.5	—	1.5	21.0	57.0	55.0	3.3	—	1.2	100	58.9
Fish meal, white	48.5	33.5	2.7	—	2.5	9.8	23.9	55.7	23.5	—	—	100	106.1
Fishmeal solubles (condensed)	90.5	58.6	25.5	—	—	6.4	40.3	39.2	14.3	—	—	100	67.8
Greaves	93.7	45.7	30.8	—	4.8	12.4	68.6	67.2	12.5	—	—	100	91.0
Hatchery waste (dried)	90.3	50.3	15.0	—	1.0	24.0	46.0	56.4	0.8	—	—	100	72.3
Meat and bone meal*	89.2	72.2	13.2	—	—	3.8	19.0	56.4	0.8	—	—	100	72.3
Pure meat meal	90.5	60.0	11.0	—	0.5	19.0	46.0	56.4	0.8	—	—	100	72.3
Feeding meat meal (high fat)													

* Brands of meat and bone and of feeding meat meal containing not more than 4 per cent of oil are now available.

Composition and Nutritive Value of Feedingstuffs—continued

	Composition per cent as shown by chemical analysis						Digestible nutrients per cent				Calculated from digestible nutrients			
	(1) Dry Matter	(2) Crude Protein	(3) Oil (Ether Extract)	(4) Crude Fibre	(5) Carbohydrate (Nitrogen-free Extractives)	(6) Ash	(7) True Protein	(8) Dig. Crude Protein	(9) Dig. Oil (Dig. Ether Extract)	(10) Dig. Fibre	(11) Dig. Carbohydrate (Dig. Nitrogen-free Extractives)	V. (12)	Starch Equivalent (13)	Protein Equivalent (14)
14. FEEDING STUFFS OF ANIMAL ORIGIN <i>contd</i>														
Feeding meat meal (low fat)	93.0	66.7	2.9	—	4.0	19.4	51.5	58.6	2.4	—	3.9	100	59.6	51.0
Milk, buttermilk	9.2	3.6	0.8	—	4.1	0.7	3.6	3.4	0.8	—	4.1	100	9.2	3.4
Milk, cows, whole	12.8	3.4	3.9	—	4.8	0.7	3.4	3.2	3.9	—	4.8	100	17.1	3.2
Milk, separated	9.4	3.5	0.1	—	5.0	0.8	3.5	3.3	0.1	—	5.0	100	8.3	3.3
Milk, skimmed, deep set	9.7	3.5	0.4	—	5.0	0.8	3.5	3.3	0.4	—	5.0	100	9.1	3.3
Milk, skimmed, shallow set	10.0	3.5	0.7	—	5.0	0.8	3.5	3.3	0.7	—	5.0	100	9.8	3.3
Milk, whey	6.6	0.7	0.2	—	5.0	0.7	0.7	0.6	0.2	—	5.0	100	6.1	0.6
Colostrum (first drawn)	25.5	17.6	4.2	—	2.7	1.0	—	—	—	—	—	—	—	—
Dried whole milk	95.8	25.5	26.5	—	37.4	6.4	—	—	—	—	—	—	—	—
Dried separated milk	89.7	32.8	1.5	—	47.9	7.5	—	—	—	—	—	—	—	—
Condensed whole milk (unsweetened)	38.6	11.2	11.4	—	14.0	2.0	—	—	—	—	—	—	—	—
Condensed separated milk (unsweetened)	31.4	12.4	0.3	—	15.7	3.0	—	—	—	—	—	—	—	—
Dried buttermilk	90.0	35.3	7.0	—	40.0	7.7	—	—	—	—	—	—	—	—
Semi-solid buttermilk	29.9	11.8	2.4	—	13.2	2.5	—	—	—	—	—	—	—	—
Whey paste	46.0	6.2	0.8	—	35.0	4.0	—	—	—	—	—	—	—	—
Dried whey	92.2	12.6	1.4	—	70.5	7.7	—	—	—	—	—	—	—	—

Composition and Nutritive Value of Feedingstuffs—continued

	Composition per cent as shown by chemical analysis							Digestible nutrients per cent				Calculated from digestible nutrients		
	Dry Matter (1)	Crude Protein (2)	Oil (Ether Extract) (3)	Crude Fibre (4)	Carbohydrate (Nitrogen-free Extractives) (5)	Ash (6)	True Protein (7)	Dig. Crude Protein (8)	Dig. Oil (Dig. Ether Extract) (9)	Dig. Fibre (10)	Dig. Carbohydrate (Dig. Nitrogen-free Extractives) (11)	V. (12)	Per 100 lb	
													Starch Equivalent (13)	Protein Equivalent (14)
15. BY-PRODUCTS <i>contd</i>														
Biscuit meal (medium fat)	90.2	8.4	20.2	1.1	57.0	3.5								
Biscuit meal (high fat)	90.1	6.3	40.0	1.1	39.4	3.3								
Bracken roots	22.8	2.4	0.2	5.4	12.8	2.0								
Bracken roots (dried)	90.0	9.5	1.2	20.0	51.0	8.3								
Bread (stale)	66.2	8.0	0.7	0.6	55.5	1.4								
Bread (meal)	90.7	13.0	0.9	0.8	73.0	3.0								
Broad bean pod meal	90.0	15.0	1.0	16.0	51.4	6.6	10.9	10.1	0.6	9.3	40.4		53.6	8.0
Brussels sprouts (dried)	90.3	20.7	2.7	11.0	35.7	20.2								
Brussels sprouts (stalks)	15.8	4.0	0.4	2.2	7.6	1.6								
Burdock roots	23.0	2.2	0.1	1.6	18.1	1.0								
Cabbage leaves (dried)	86.0	17.5	2.1	8.5	43.8	14.1								
Cabbage meal (dried)	95.0	22.9	5.4	7.1	47.7	11.9								
Cacao shells	89.1	14.5	3.1	18.3	46.5	6.7								
Carrot meal (extracted)	90.0	7.5	0.9	5.5	69.1	7.0								
Carrot slices (dried)	86.2	7.9	2.1	10.7	56.7	8.8								
Cashew kernel husks	90.8	12.4	11.3	11.3	53.9	1.9								
Celery leaves (dried)	92.7	18.9	2.9	4.7	53.7	12.5								
Celery pencils (dried)	87.1	10.9	1.1	6.3	59.4	9.4								

[illegible]

Composition and Nutritive Value of Feedingsuffs—continued

	Composition per cent as shown by chemical analysis							Digestible nutrients per cent				Calculated from digestible nutrients		
	Dry Matter (1)	Crude Protein (2)	Oil (Ether Extract) (3)	Crude Fibre (4)	Carbohydrate (Nitrogen-free Extractives) (5)	Ash (6)	True Protein (7)	Dig. Crude Protein (8)	Dig. Oil (Dig. Ether Extract) (9)	Dig. Fibre (10)	Dig. Carbohydrate (Dig. Nitrogen-free Extractives) (11)	V. (12)	Per 100 lb	
													Starch Equivalent (13)	Protein Equivalent (14)
15. BY-PRODUCTS <i>contd</i>														
Hops, spent, dried	89.1	15.3	6.8	21.0	39.6	6.4	13.6	4.7	4.4	3.6	19.0		29.8	3.8
Hop meal	95.0	27.5	9.9	17.0	32.0	6.6	—	—	—	—	—		55.8	—
Horse-chestnut meal (alcohol-extracted)	90.0	6.6	6.7	7.2	67.1	2.4	—	—	4.0	—	48.2		55.0	—
Horse chestnut meal (water-extracted)	90.0	7.0	7.0	7.6	66.2	2.2	—	—	4.6	—	46.2		—	—
Kaffir corn residues	89.2	16.9	3.1	7.3	48.2	13.7	—	1.3	0.7	17.2	33.4		46.7	—
Lentil husks (chaff or hulls)	88.0	11.1	0.7	25.6	47.5	3.1	—	—	—	—	—		—	—
Lime fruits	31.9	3.6	3.0	13.5	9.7	2.1	—	—	—	—	—		—	—
Linseed bran (see flax by-products)	91.1	13.9	18.8	10.9	35.7	11.8	—	—	—	—	—		—	—
Linseed sheaf meal	88.9	9.3	10.7	38.1	27.7	3.1	—	—	—	—	—		—	—
Locust bean germ meal	91.0	55.3	5.2	2.3	21.5	6.7	—	—	—	—	—		—	—
Processed lucerne cake (from chlorophyll manu- facture)	90.0	22.2	4.5	21.2	33.6	8.5	—	—	—	—	—		—	—
Maize bran	88.2	8.4	4.2	11.7	62.0	1.9	7.7	5.5	3.6	3.9	53.4		67.0	5.1
Maize, gluten feed	89.6	23.5	3.4	3.5	56.7	2.5	21.9	20.0	2.7	2.5	49.3		75.6	19.2
Maize, gluten meal	90.0	35.5	4.7	2.1	47.5	1.1	35.2	30.6	4.4	—	42.6		81.5	30.4
Maize malt culms	86.5	20.7	14.5	5.8	39.6	5.9	13.9	17.4	12.4	4.5	34.9		59.4	14.0
Maize, feeding meal from corn flour	89.8	20.4	4.4	5.0	59.0	1.0	18.9	17.0	3.5	3.3	51.3		77.6	16.2
Maize, sprouted	22.4	3.1	1.0	1.1	16.7	0.5	—	—	—	—	—		—	—
Maize, starch feed	90.9	22.8	6.9	7.6	52.7	0.9	22.0	19.2	6.2	5.5	44.8		81.8	18.8

Maize pulp (wet)	11.0	3.1	0.8	0.6	6.1	0.4	11.6	11.0	2.4	4.5	56.4	71.5	9.9
Maize cobs (green)	28.2	2.5	0.7	4.3	19.9	0.8							
Maize cobs (ripe)	51.7	4.8	1.6	5.8	38.5	1.0							
Malt, dry	93.4	13.8	3.1	9.0	64.9	2.6							
Millet meal, Egyptian	87.5	13.1	2.1	8.6	56.5	7.2							
Oat bran } (from preparation of oatmeal)	90.5	8.0	3.6	21.9	51.0	6.0	7.6	4.0	2.0	8.1	35.6	45.5	3.8
Oatmeal	91.8	16.0	6.7	1.6	65.5	2.0	14.5	12.0	5.4	0.8	48.0	71.1	11.2
Oat clippings	90.0	7.3	1.7	27.2	45.3	8.5	—	—	0.4	10.9	19.4	20.6	—
Oat husks	94.0	2.0	1.0	33.0	54.0	4.0							
Oat kernels	91.7	16.2	6.4	1.9	65.3	1.9							
Oatmeal seeds (coarse)	91.0	5.0	2.0	30.0	51.0	3.0							
Oatmeal seeds (fine)	90.9	10.1	5.2	14.5	57.8	3.3							
Oat feed (ordinary)	92.0	5.5	2.4	27.6	52.5	4.0							
Oat feed (high grade)	91.0	10.3	5.0	17.5	53.7	4.5							
Oat cockle	87.7	13.0	5.8	3.6	62.7	2.6							
Oat dust	93.0	10.0	11.0	13.0	55.0	4.0							
Parsnip seed meal	93.2	18.0	22.7	17.5	28.1	6.9							
Pea germ meal	92.5	32.0	2.9	2.2	48.9	6.5							
Pea husks (chaff or hulls)	87.8	5.3	0.7	47.9	31.1	2.8	4.9	3.6	0.5	45.0	27.9	64.2	3.4
Pea pod meal (from canning industry)	90.0	13.5	1.2	15.2	54.1	5.7	8.2	9.7	0.8	9.6	41.5	54.8	7.0
Penicillin felts (containing added chalk)	19.4	5.0	0.5	0.2	7.7	6.0							
Penicillin felts (dried)	95.2	42.3	4.0	9.8	27.9	11.2	31.1	31.3	2.0	8.6	22.8	62.2	25.7
Plantain meal	86.2	2.2	0.7	0.7	80.6	2.0							
Potato sludge	86.0	3.4	0.1	8.8	68.2	5.5	—	—	—	1.1	52.5	51.0	—
Potato slump	90.0	24.3	3.7	9.5	40.8	11.7	21.5	12.2	1.8	2.0	20.4	31.8	10.8
Potato pulp (dry)	86.0	3.4	0.1	8.8	68.2	5.5	—	—	—	2.1	56.6	55.8	—
Potato cossettes (meal)	88.0	8.6	0.5	2.0	73.4	3.5	4.6	4.7	—	1.0	63.4	68.8	2.7
Potato flakes	90.0	8.2	0.3	2.1	75.6	3.8	—	3.8	—	1.0	70.8	75.2	—
Potato slices	89.0	9.3	0.2	1.6	74.0	3.9	—	4.0	—	0.8	68.6	73.2	—
Potato peelings (machine)	11.0	1.0	0.8	1.9	6.6	0.7							
Potato dust	94.9	9.3	0.2	2.6	76.6	6.2							
Potato crisp residues	92.1	7.7	32.8	2.4	43.9	5.3							
Restaurant waste (dried)	91.7	21.6	7.2	0.7	47.4	14.8							
Rice meal	91.1	12.9	13.7	6.4	49.5	8.5	12.0	7.5	11.6	1.6	39.0	72.3	7.0

Composition and Nutritive Value of Feedingstuffs—continued

	Composition per cent as shown by chemical analysis							Digestible nutrients per cent				Calculated from digestible nutrients	
	Dry Matter (1)	Crude Protein (2)	Oil (Ether Extract) (3)	Crude Fibre (4)	Carbohydrate (Nitrogen-free Extractives) (5)	Ash (6)	True Protein (7)	Dig. Crude Protein (8)	Dig. Oil (Dig. Ether Extract) (9)	Dig. Fibre (10)	Dig. Carbohydrate (Dig. Nitrogen-free Extractives) (11)	V. (12)	Per 100 lb Starch Equivalent (13) Protein Equivalent (14)
15. BY-PRODUCTS <i>contd</i>													
Rice sludge, dried	86.0	26.2	2.1	1.1	55.2	1.4	21.0	21.5	1.0	0.7	50.3		61.7
Rose hip residues, fresh	34.9	2.8	2.1	15.8	13.3	0.9							18.9
Rose hip residue meal, dried	91.6	6.9	3.9	36.2	40.3	4.3							
Rye bran	87.5	16.7	3.1	5.2	58.0	4.5	15.0	12.5	2.4	1.7	42.9		46.9
Rye-grass stover	81.0	4.7	1.4	21.8	48.4	4.7							11.6
Sainfoin tails (milled)	90.0	31.4	5.9	10.8	37.5	4.4							
Seaweed meal (dried):													
Laminaria	83.7	11.4	1.1	8.6	45.8	16.8	9.7	6.1	0.9				5.2
Fucus	88.7	5.2	4.2	9.4	53.6	16.3	0.0	0.0	4.0				0.0
Sheaf meal (oats and legumes)	90.3	11.4	2.1	24.4	48.0	4.4							
Soya bean husks	88.5	7.9	3.7	39.3	32.6	5.0							
Straw pulp (alkaline treatment)*													
From barley straw	16.9	0.8	0.3	7.8	6.8	1.2							
From oat straw	18.3	0.5	0.3	9.3	7.0	1.2							
From wheat straw	19.4	0.4	0.2	9.9	7.7	1.2							
Sugar beet, frozen (dried)	92.5	5.5	1.2	8.7	72.7	4.4	1.6	1.0	—	2.8	8.7		11.7
Sugar beet pulp, wet	15.0	1.6	0.1	3.1	9.6	0.6							1.0
Sugar beet pulp (double pressed)	19.3	2.1	0.1	3.2	12.8	1.1							

* Means of trials at the Tealott's Hill Research Station.

Sugar beet pulp, dried	89.0	8.9	0.6	18.3	59.1	3.1	8.6	5.3	—	16.3	54.0	60.0	5.0
Sugar beet pulp, molassed	90.0	10.8	0.4	15.1	58.2	5.5	7.5	6.3	—	13.5	53.0	58.3	4.6
Sugar beet molasses	74.7	3.5	—	—	66.0	5.2	—	1.2	—	—	59.2	51.6	—
Sugar beet tailings	14.3	1.0	0.1	1.7	8.5	3.0	—	1.1	—	—	58.2	50.6	—
Sugar cane molasses	74.2	3.1	—	—	64.7	6.4	—	—	—	—	—	—	—
Sultanas (dried)	76.7	1.4	0.7	1.1	70.9	2.6	—	—	—	—	—	—	—
Sunflower seed husks	91.0	11.6	17.1	29.4	25.5	7.4	—	—	—	—	—	—	—
Swill, urban (processed)	29.7	3.9	2.3	1.5	17.6	4.4	—	—	1.9	0.7	15.8	22.2	—
Swill, school (deep stew)	18.0	3.0	5.0	0.7	8.2	1.1	—	—	0.1	1.9	80.3	83.5	—
Tapioca flour	88.0	1.8	0.5	2.5	81.1	2.1	—	—	—	—	—	—	—
Tapioca ampas	87.3	0.9	0.2	4.9	80.5	0.8	—	—	—	—	—	—	—
Tapioca roots	87.1	1.9	0.3	1.9	81.6	1.4	—	—	—	—	—	—	—
Trefol "cosh" (pods)	85.7	14.0	2.0	23.0	40.0	6.7	—	—	—	—	—	—	—
Trefoil screenings	89.9	18.5	4.2	16.4	39.6	11.2	—	—	—	—	—	—	—
Tomato flour (skins and seeds)	93.3	23.1	20.5	25.7	17.8	6.2	—	—	—	—	—	—	—
Wafer waste	88.2	12.3	3.2	1.9	69.3	1.5	—	—	—	—	—	—	—
Walnut shells	92.3	1.7	0.7	56.6	31.9	1.4	—	—	—	—	—	—	—
Wheat germ meal (vacuum heated)	89.8	32.0	9.2	2.0	41.9	4.7	—	—	—	—	—	—	—
Wheat malt bran	90.6	12.9	3.3	10.2	61.1	3.1	—	—	—	—	—	—	—
Wood sugar syrup	71.6	0.6	—	—	66.5	4.5	—	—	—	—	—	—	—

WHEAT FEEDS:													
Pure Grades													
Finest grade, fine middlings	86.7	17.0	4.2	2.3	60.8	2.4	16.0	12.6	3.7	—	51.1	69.0	12.1
Second grade, coarse middlings or sharps (fine wheat feed) *	86.0	15.9	4.5	6.0	55.9	3.7	14.4	11.6	3.9	1.4	45.9	56.5	10.8
Fourth grade, bran	87.0	15.1	3.8	9.5	52.8	5.8	13.1	10.9	2.6	2.2	37.4	42.6	9.9
Broad bran	87.0	14.7	4.0	10.3	52.1	5.9	12.7	11.0	2.8	2.2	36.9	42.6	10.0
War-time Grades													
Fine wheat feed (75 per cent extraction)	87.0	16.3	5.1	7.5	54.1	4.0	—	12.2	3.1	2.0	41.2	49.0	—
Fine bran (85 per cent extraction)	87.0	15.2	4.5	9.4	53.5	4.4	—	10.8	2.6	1.9	39.6	44.0	—
Coarse bran (85 per cent extraction)	87.0	15.0	4.3	10.3	52.3	5.1	—	11.0	0.9	2.8	37.5	40.4	—

* Home-produced middlings are now available under the name of Weatings (with a guarantee of not more than 6.0 per cent of fibre).

Composition and Nutritive Value of Feedingstuffs—continued

	Composition per cent as shown by chemical analysis							Digestible nutrients per cent				Calculated from digestible nutrients		
	(1) Dry Matter	(2) Crude Protein	(3) Oil (Ether Extract)	(4) Crude Fibre	(5) Carbohydrate (Nitrogen-free Extractives)	(6) Ash	(7) True Protein	(8) Dig. Crude Protein	(9) Dig. Oil (Dig. Ether Extract)	(10) Dig. Fibre	(11) Dig. Carbohydrate (Dig. Nitrogen-free Extractives)	V. (12)	Per 100 lb	
													Starch Equivalent (13)	Protein Equivalent (14)
15. BY-PRODUCTS <i>contd</i>														
WHEAT FEEDS: War-time Grades <i>contd</i>														
Fine millers' offals (85 per cent extraction)*.	87.0	14.1	4.3	10.3	53.4	4.9	—	9.9	2.4	3.3	38.7	77	43.4	—
Coarse millers' offals (85 per cent extraction)*.	87.0	12.3	3.9	13.4	51.4	6.0	—	7.6	0.1	4.4	34.8	75	34.9	—
Yeast, dried	93.7	41.5	1.0	0.2	41.4	9.6	35.3	35.6	0.4	—	34.1	100	68.3	32.5
Yeast, lye	12.2	6.5	0.1	0.3	4.0	1.3	—	—	—	—	—	—	—	—
Yeast, wood sugar (dried)	90.0	47.1	1.3	—	34.3	7.3	37.0	42.4	0.3	—	30.2	100	61.2	37.3

* Wheat diluted with 10 per cent barley before milling.

	Composition per cent as shown by chemical analysis						Digestible nutrients per cent				Calculated from digestible nutrients
	Dry Matter (1)	Crude Protein (2)	Oil (Ether Extract) (3)	Crude Fibre (4)	Carbohydrate (Nitrogen-free Extractives) (5)	Ash (6)	Dig. Crude Protein (7)	Dig. Oil (Dig. Ether Extract) (8)	Dig. Fibre (9)	Dig. Carbohydrate (Dig. Nitrogen-free Extractives) (10)	
PIGS											
1. ROOTS											
Tulip bulbs	48.0	5.2	0.7	2.0	37.4	2.7	3.5	0.5	1.0	35.0	40.6
2. GREEN FOODS											
Kale, marrowstem (minced)	14.0	2.2	0.5	2.5	6.9	1.9	1.4	0.2	1.0	5.8	8.5
3. GRASSES											
Pasture grass, closely grazed	20.0	5.2	0.8	3.4	8.9	1.7	3.5	—	1.9	6.4	11.8
Pasture grass, rotational grazing	20.0	3.4	0.6	3.9	10.5	1.6	1.9	—	2.1	7.3	11.3
4. CEREALS											
Barley meal	86.0	10.5	1.5	4.8	66.6	2.6	8.6	1.2	0.5	59.1	70.9
Maize meal (dry fed)	87.0	9.6	4.4	2.0	69.4	1.6	7.5	2.8	0.5	63.5	77.8
Maize meal (soaked)	87.0	9.6	4.4	2.0	69.4	1.6	7.7	2.7	0.7	63.8	78.3
Maize meal (cooked)	87.0	9.4	4.5	1.6	69.7	1.8	8.1	2.9	0.4	64.4	79.4
Maize (flaked)	89.0	10.4	4.4	1.5	71.6	1.1	9.9	2.7	0.5	69.5	86.0
Oats (Sussex ground)	87.0	11.6	5.6	11.4	54.8	3.6	8.7	4.7	5.4	44.5	69.2
Oats (farm ground)	87.0	11.2	4.7	10.0	58.2	2.9	9.6	4.1	—	43.2	62.0
Oats (crushed)	87.0	9.7	4.8	11.1	58.2	3.2	6.7	3.1	—	38.3	52.0

Per 100 lb

Total Digestible
Nutrients

(11)

Composition and Nutritive Value of Feedingstuffs—continued

	Composition per cent as shown by chemical analysis						Digestible nutrients per cent				Calculated from digestible nutrient
	(1) Dry Matter	(2) Crude Protein	(3) Oil (Ether Extract)	(4) Crude Fibre	(5) Carbohydrate (Nitrogen-free Extractives)	(6) Ash	(7) Dig. Crude Protein	(8) Dig. Oil (Ether Extract)	(9) Dig. Fibre	(10) Dig. Carbohydrate (Nitrogen-free Extractives)	
PIGS											
4. CEREALS <i>contd</i>											
Sorghum (ground)	87.2	10.7	3.2	2.3	69.7	1.3	8.2	2.0	1.4	64.8	78.9
5. OIL CAKES AND MEALS											
Ground-nut meal, decorticated extracted	88.0	53.8	0.6	5.2	22.5	5.9	50.0	0.3	3.6	19.1	73.4
Palm kernel meal, extracted	90.0	19.0	2.0	16.0	49.0	4.0	11.4	0.5	5.8	37.6	55.9
Soya bean meal, extracted	88.7	44.7	1.5	5.1	31.9	5.5	38.4	1.3	3.0	28.3	72.6
6. LEGUMES											
Bean meal	86.8	27.6	1.0	9.6	45.6	3.0	22.2	0.3	2.7	40.8	66.4
7. FEEDINGSTUFFS OF ANIMAL ORIGIN											
Fish meal, White	87.5	62.4	3.6	—	1.0	20.5	59.1	1.1	—	0.9	63.0
Meat meal	92.1	65.9	10.2	—	2.3	13.7	61.9	9.1	—	2.3	84.7
Meat meal (extracted)	93.0	66.6	3.0	—	4.0	19.4	58.6	2.4	—	4.0	68.0
Whale meat meal	94.4	87.8	3.5	—	1.1	2.0	76.9	3.4	—	1.1	85.6
8. BY-PRODUCTS											
Fodder cellulose (from wheat straw by paper process)	90.0	0.3	0.5	71.8	14.6	2.8	—	—	61.1	9.8	70.9
Horse-chestnut meal (alcohol extracted)	66.6	6.6	6.2	7.2	67.1	2.4	1.3	2.8	1.8	1.8	6.2

BY-PRODUCTS *contd*

Horse-chestnut meal (water extracted)	90.0	7.0	7.0	7.6	66.2	2.2	1.6	3.6	1.2	48.3	59.2
Lucerne meal	91.4	20.0	4.7	22.7	34.8	9.2	11.7	1.4	7.4	24.5	46.8
Crude carcass meal	90.5	44.5	17.4	—	4.6	24.0	37.2	15.6	—	—	72.3
Penicillin felts (dried)	95.2	42.3	4.0	9.8	27.9	11.2	28.0	1.1	8.0	18.3	56.8
Potato meal	88.0	8.6	0.5	2.0	73.4	3.5	3.4	0.2	1.3	70.7	75.7
Potato flakes	90.0	8.2	0.3	2.1	75.6	3.8	6.7	—	1.6	75.6	83.9
Potato slices	89.0	9.3	0.2	1.6	74.0	3.9	7.0	—	0.5	72.5	80.0
Potato peelings (hand)	21.2	2.1	0.1	0.7	17.0	1.3	1.6	—	0.5	16.4	18.5
Sago pith meal	87.0	1.7	0.4	4.3	77.2	3.4	0.0	0.3	—	66.0	66.7
Seaweed meal (dried):											
Laminaria	83.7	11.4	1.1	8.6	45.8	16.8	1.3	0.8	25.5	28.6	
Fucus	88.7	5.2	4.2	9.4	53.6	16.3	0.0	3.4	26.7	34.4	
Sugar beet, grated	26.2	1.6	0.2	1.1	22.2	1.1	0.6	—	1.0	21.6	23.2
Sugar-beet pulp, dried	90.0	8.9	0.6	18.3	59.1	3.1	3.1	—	15.4	51.5	70.0
Sugar-beet pulp, molassed	90.0	10.8	0.4	15.1	58.2	5.5	2.6	—	12.7	51.9	67.2
Swill:											
Urban swill, winter	25.0	3.7	3.0	1.4	14.5	2.4	2.3	2.3	0.8	13.9	22.2
Urban swill, winter (processed)	31.9	4.7	3.8	1.8	18.5	3.1	2.9	2.9	1.0	17.7	28.1
Urban swill, summer	25.0	4.1	3.1	2.4	12.4	3.0	2.7	2.5	0.9	10.9	20.1
Urban swill, summer (processed)	30.1	4.9	3.7	2.9	15.0	3.6	3.3	3.0	1.1	13.2	24.4
Urban swill, summer (dried and balanced)	89.7	24.8	10.9	7.8	29.8	16.4	18.7	8.9	3.6	19.2	61.5
Military camp swill (meat rich)	31.4	6.4	8.9	0.5	13.7	1.9	5.8	8.5	0.3	13.5	38.7
Military camp swill (ordinary quality)	25.0	4.2	4.2	1.5	12.3	2.8	2.6	3.2	0.8	11.8	22.4
Whale meat meal (high protein, low ash)	94.4	87.7	3.4	—	1.2	2.1	76.9	3.3	—	1.1	85.4
Wheat feeds, War-time grades:											
Fine wheatfeed (75 per cent extraction)	87.0	16.3	5.1	7.5	54.1	4.0	12.7	3.5	1.6	41.2	63.4
Fine bran (85 per cent extraction)	87.0	15.2	4.5	9.4	53.5	4.4	11.9	3.0	1.6	39.7	60.0
Coarse bran (85 per cent extraction)	87.0	15.0	4.3	10.3	52.3	5.1	10.3	1.5	1.2	33.3	48.2
Fine millers' offals (85 per cent extraction)*	87.0	14.1	4.3	10.3	53.4	4.9	9.0	2.7	1.6	34.7	51.4
Coarse millers' offals (85 per cent extraction)	87.0	12.3	3.9	13.4	51.4	6.0	6.7	1.8	1.7	28.7	41.2
Coarse millers' offals (72 per cent extraction)	86.1	15.4	3.5	5.8	57.5	3.9	12.0	2.4	1.3	43.9	62.5
Yeast, dried	93.7	41.5	1.0	0.2	41.4	9.6	37.1	—	—	38.6	75.7

* Wheat diluted with 10 per cent barley before milling.

Mineral Composition of some Common Feedingstuffs

	Total Ash per cent	Lime (CaO) per cent	Phosphoric Acid (P_2O_5) per cent	Potash (K_2O) per cent	Chlorine (Cl) per cent
Mangolds	0.9	0.02	0.09	0.45	0.16
Potatoes	1.0	0.03	0.18	0.60	0.04
Potatoes (dried)	3.5	0.08	0.39	2.19	0.30
Potato peelings (hand)	1.3	0.04	0.10		0.07
Swedes	0.7	0.08	0.08	0.30	0.04
Cabbage	1.2	0.20	0.15	0.40	0.02
Kale, thousandhead	1.7	0.39	0.13	0.52	0.16
Kale, marrowstem	1.9	0.43	0.12	0.55	0.21
Sugar beet tops	3.4	0.34	0.11	0.58	0.36
Chicory leaves, dried early July	19.2	1.12	0.95	4.50	0.90
Tulip bulbs	2.7	0.08	0.38		
Pasture grass (rotational close- grazing)	2.0	0.28	0.16	0.60	0.19
Grassmeal (18 per cent protein)	8.8	1.20	0.75	2.70	0.80
Vetches, in flower	1.5	0.50	0.15	0.50	
Clover, red, flowering	1.6	0.40	0.15	0.50	0.05
Amer. crimson clover, dried in pre-flower	12.0	1.76	0.71		
Amer. crimson clover, dried in early flower	10.7	1.89	0.73		
Ladino clover, dried in pre- flower	13.3	2.62	0.95		
Ladino clover dried in early flower	11.9	2.48	0.98		
Strawberry clover, dried in early flower	13.2	2.75	0.96		
Bird's foot trefoil dried in mid- August	10.5	2.38	0.76		
Lucerne (before bud)	1.8	0.45	0.13	0.48	0.05
Lucerne (in bud)	1.8	0.77	0.14	0.56	0.05
Lucerne (early flower)	2.4	0.96	0.12	0.43	0.08
Lucerne meal	9.2	2.73	0.78	1.82	0.55
Sainfoin (early flower)	1.4	0.46	0.14	0.28	0.07
Sainfoin (full flower)	1.6	0.54	0.14	0.31	0.07
Lupin, sweet yellow (in flower)	1.5	0.43	0.11	0.23	0.06
Pea-pod meal	5.7	1.37	0.54	1.32	0.32
Broad-bean-pod meal	6.6	0.83	0.54	2.34	0.47
Pea-pod silage	1.8	0.50	0.14		0.05
Pea-haulm-plus-pod silage	4.1	0.54	0.16	0.40	0.11
Meadow hay, good	6.8	1.00	0.50	1.60	0.37
Red clover hay	7.0	1.60	0.39	2.20	0.24
Sainfoin hay	5.8	1.55	0.53	1.28	0.27
Seeds, hay	6.3	2.00	0.60	1.80	0.30
Lucerne hay (half flower)	8.0	2.74	0.51	1.52	0.34
Oat straw	4.9	0.36	0.18	1.50	0.30
Wheat straw	5.3	0.29	0.13	0.80	0.20
Bean straw (including pods)	4.6	1.20	0.30	1.90	
Pea straw	6.6	1.60	0.40	1.00	0.40
Timothy straw	3.3	0.31	0.17		
Barley	2.6	0.07	0.84	0.57	0.12
Maize	1.3	0.02	0.82	0.40	0.07
Oats	3.1	0.14	0.81	0.55	0.07
Sorghum grain	1.3	Trace	0.54	0.46	0.03
Wheat	1.7	0.05	0.86	0.60	0.08

Mineral Composition of some Common Feedingstuffs—continued

	Total Ash per cent	Lime (CaO) per cent	Phosphoric Acid (P_2O_5) per cent	Potash (K_2O) per cent	Chlorine (Cl) per cent
ans	3.2	0.18	0.88	1.28	0.03
as	2.8	0.10	0.90	1.00	0.04
erne seed meal	4.4	0.29	1.34	1.29	0.13
pin seeds (sweet yellow)	3.8	0.29	1.24	1.43	0.04
d clover seed meal	6.7	0.32	1.33		0.13
egrass seed meal	4.1	0.29	0.69	0.70	0.11
nfoin seed meal (unmilled seed)	4.0	1.02	0.91	1.23	0.11
nfoin seed meal (milled seed)	3.5	0.23	1.11		0.11
an	5.8	0.20	2.80	1.50	0.09
iddlings (weatings)	3.7	0.13	1.50	1.40	0.07
stor bean meal (de-toxicated)	6.4	1.02	1.70		0.10
conut cake	5.6	0.16	1.27	2.41	0.65
otton cake, undec.	5.8	0.30	2.50	1.60	0.05
ottonseed meal	6.0	0.36	2.70	1.60	0.04
round-nut cake, undec.	5.7	0.20	1.00	1.00	
round-nut cake, dec.	5.8	0.20	1.30	1.50	0.03
orse-chestnut meal (alcohol- extracted)	2.4	0.31	0.25		0.08
orse-chestnut meal (water extracted)	2.2	0.52	0.36		0.06
nseed cake	5.2	0.51	1.70	1.30	0.09
lm-kernel cake	3.8	0.30	1.10	0.50	0.16
ya bean cake	5.4	0.30	2.00	1.80	0.03
ya bean meal (extracted)	5.5	0.30	2.10	1.90	0.03
h meal, white	22.0	10.00	9.00	1.20	1.00
h solubles (condensed)	9.8	0.11	1.59		2.64
eat meal, pure	3.8	0.40	0.70	0.10	0.27
eat meal	19.0	8.00	7.20	0.70	1.20
eat and bone meal	24.0	10.50	9.30	0.80	1.40
ood meal	2.7	0.05	0.22	0.31	0.85
east, dried	9.6	0.30	5.50	2.00	0.03
enicillin felts (containing added chalk)	6.0	2.83	1.46		0.08
enicillin felts (dried)	11.2	0.81	5.59		0.28
ilk, whole	0.8	0.17	0.20	0.20	0.10
ilk, separated	0.8	0.15	0.20	0.20	0.10
hey	0.7	0.10	0.10	0.15	0.07
rewers' grains, dried	3.9	0.40	1.60	0.20	0.06
istillers' grains, dried	1.8	0.40	0.68	0.20	0.06
ocust bean meal	4.0	0.85	0.26	0.70	0.20
maize meal, degermed	0.9	0.02	0.39	0.33	0.03
maize, flaked	0.9	Trace	0.60	0.25	Trace
maize germ meal	3.6	0.10	0.90	1.30	0.03
maize gluten meal	1.1	0.05	0.30	0.05	
maize gluten feed	2.5	0.10	0.70	0.20	
ice meal	8.6	0.10	2.50	0.70	0.14
ose hip residue meal, dried	4.3	1.32	0.38		
ago pith meal	3.4	0.33	0.11	0.54	0.56
seaweed meal (dried):					
Laminaria	16.8	4.62	0.21	1.25	0.69
Fucus	16.3	1.60	0.11	1.80	1.32
ugar beet pulp, dried	3.1	1.20	0.18	0.59	0.05
ugar beet pulp, molassed	5.5	1.20	0.17	1.34	0.48

Mineral Composition of some Common Feedingstuffs—continued

—	Total Ash per cent	Lime (CaO) per cent	Phosphoric Acid (P_2O_5) per cent	Potash (K_2O) per cent	Chlorine (Cl) per cent
Swill, urban	2.4	0.23	0.18		0.19
Swill, urban, processed	3.1	0.29	0.23		0.24
Swill, urban, dried and balanced	16.4	4.80	3.45		0.75
Swill, military camp (meat rich)	1.9	0.17	0.24		0.28
Swill, military camp (ordinary quality)	2.8	0.34	0.14		0.24
School swill (deep stew)	1.1	0.09	0.14		
Tapioca flour	2.2	0.22	0.25	1.04	0.02
Steamed bone flour (dry matter)	88.7	45.80	31.10	Trace	0.02
Di-calcium phosphate	84.3	37.70	44.82	Trace	0.02
Whalemeat meal (high protein, low ash)	2.1	0.05	0.90		0.03
Whale solubles (condensed) . .	5.7	0.10	0.75		2.10

Appendix

Note on Fertilisers and Feeding Stuffs Act, 1926

Under Section 1 (1) of the Fertilisers and Feeding Stuffs Act, 1926, every person who sells or uses as food for cattle or poultry any article included in the first column of Part II of the First Schedule, or in Part II of the Second Schedule to the Act, whatever may be the name under which the article is sold, is required to give the purchaser on or before delivery, or as soon as reasonably practicable thereafter, a statement in writing (referred to in the Act as "statutory statement") containing the following particulars:

- (a) the name under which the article is sold
- (b) such particulars (if any) of the nature, substance, or quality of the article as are mentioned in the second column of such Schedule
- (c) the name of any ingredient listed in the Third Schedule.

This requirement, however, does not apply (1) to sales of two or more articles that are requested at the request of the purchaser before delivery to him; and (2) to sales of small quantities (i.e., 56 lb or less) if the article sold is taken in the presence of the purchaser in a parcel or receptacle bearing a conspicuous label on which the above-mentioned particulars are marked.

It is provided in the Act that a statutory statement given by a seller of any such article shall have effect as a written warranty by the seller that the particulars contained in the statutory statement are correct. Further, in the case of articles not included in the Schedules, any voluntary statement as to the amounts of any ingredient of a feeding stuff has effect as a warranty.

Every purchaser of a feeding stuff in respect of which a warranty has been given has the right under the Act to have a sample taken and analysed, and to be furnished with a certificate of the result of the analysis. This certificate will show him whether or not the article complies with the warranty.

All that the farmer or other purchaser has to do is to (a) request the Official Sampler appointed by the County Council or County Borough Council, as the case may be, to take a sample, and (b) pay the prescribed fee, if any. The request should be made and posted promptly after the arrival of the consignment as the sample must be taken within fourteen days after delivery of the goods or receipt by the purchaser of the statutory statement or warranty, whichever date may be the later. If the analysis discloses a deficiency or breach of warranty, the purchaser will decide whether to make a claim against the seller or not. No other action can follow, as no prosecution can be instituted by a Local Authority against a seller in respect of any deficiency where the sample has been taken on a farm by an Official Sampler. The name and address of the nearest Official Sampler can be obtained on application to the Clerk to the Local Authority.

The particulars of the nature, substance or quality of the article required to be given in the statutory statement in compliance with paragraph (b) quoted above are set out in the following Schedules 1-5 to the Act as amended by the Fertilisers and Feeding Stuffs Regulations, 1955.

FIRST SCHEDULE

Sections 1, 2, 3, 4, 5, 8, 10, 12

ARTICLES TO WHICH ALL THE PROVISIONS OF THE ACT
ARE APPLICABLE

PART II: FEEDING STUFFS

<i>Article</i>	<i>Particulars to be contained in Statutory Statement</i>
Barley meal	None.
Barley meal, Grade II	None.

FIRST SCHEDULE. PART II: FEEDING STUFFS *continued**Particulars to be contained in
Statutory Statement*

<i>Article</i>	
Bean meal	None.
Coconut or copra cake or meal	Amounts of oil and protein respectively.
Compound cakes or meals, that is to say, any cakes or meals (other than molasses feeds and dried molassed beet pulp) consisting of a mixture of one or more of the articles mentioned in this Part of this Schedule or in Part II of the Second Schedule with any other such article or with any other substance or substances.	Amounts, if any, of oil, protein and fibre respectively.
Cotton cakes or meals, not decorticated	Amounts of oil and protein respectively.
Cotton cakes or meals from decorticated or partly decorticated cotton seed	Amounts of oil, protein and fibre respectively.
Dari or durra meal	None.
Dried plain beet pulp	Amount of fibre.
Dried molassed beet pulp	Amounts of sugar and fibre respectively.
Feeding bone flour	Amounts of phosphoric acid and protein respectively.
Feeding bone meal, ground bone, or any other bone product for feeding purposes	Amounts of phosphoric acid and protein respectively.
Feeding meat and bone meal, or any other product of meat (including whale meat) and bone for feeding purposes	Amounts of oil, protein and phosphoric acid respectively.
Feeding meat meal, or any other product of meat (including whale meat) for feeding purposes.	Amounts of oil, protein and phosphoric acid respectively.
Fish meal, white fish meal, or other product obtained by drying and grinding or otherwise treating fish or fish waste	Amounts of oil, protein, phosphoric acid and salt respectively.
Ground oats	None.
Linseed cakes and the meals of such cakes; extracted linseed meal	Amounts of oil and protein respectively.
Linseed meal	Amount of oil.
Locust bean meal	None.
Maize by-products not otherwise specifically mentioned in this Schedule	Amounts of oil, protein and fibre respectively.
Maize, flaked	Amounts of oil and protein respectively.
Maize germ cake or meal	Amounts of oil and protein respectively.
Maize gluten feed	Amounts of oil and protein respectively.
Maize meal; Indian meal	None
Molasses feeds (other than dried molassed beet pulp) including any feeding stuffs, composed of treacle or molasses with an absorbent, containing not less than 10 per cent of sugar	Amounts of sugar and fibre respectively.
Oatmeal by products	Amount of fibre.
Oil cakes or meals not otherwise specifically mentioned in this Schedule which are the product of any one undecorticated substance or seed from which oil has been removed	Amounts of oil and protein respectively.
Oil cakes or meals not otherwise specifically mentioned in this Schedule which are the product of any one decorticated or partly decorticated substance or seed from which oil has been removed	Amounts of oil, protein and fibre respectively.
Palm kernel cake or meal	Amounts of oil and protein respectively.
Pea meal	None.

FIRST SCHEDULE. PART II: FEEDING STUFFS *continued*

<i>Article</i>	<i>Particulars to be contained in Statutory Statement</i>
pe cake or meal	Amounts of oil and protein respectively.
bran or rice meal, or the by-product produced in milling shelled rice	Amounts of oil, protein and fibre respectively.
ya cake or meal	Amounts of oil and protein respectively.
acle or molasses	Amount of sugar.
heat meal	None.
heat offals or millers' offals	Amount of fibre.

The provision of this Part of this Schedule shall apply to any article described therein under whatever name it may be sold or offered for sale and notwithstanding that it contains substance not mentioned in this Part of this Schedule.

The amount, in each case, is to be stated as a definite percentage of the weight of the article, and not as a range of percentages.

Phosphoric acid is to be stated in terms of phosphoric anhydride (P_2O_5).

The amount of protein means the amount of nitrogen, other than ammoniacal or nitric nitrogen, if present, multiplied by 6.25.

SECOND SCHEDULE

Sections 1, 2, 3, 12

ARTICLES TO WHICH SOME ONLY OF THE PROVISIONS OF THE
ACT ARE APPLICABLE

PART II: FEEDING STUFFS

Article	Particulars to be contained in Statutory Statement	
falfa (lucerne) meal	Amounts of protein and fibre respectively.	
lover meal	Amounts of protein and fibre respectively.	
dried brewery and distillery grains	Amounts of oil and protein respectively.	
dried grass;	as defined in the Fourth Schedule	Amount of protein.
dried grass (maintenance quality);		
dried green fodder crops;		
dried green roughage		
dried yeast		Amount of protein.
feeding dried blood		Amount of protein.
salt culms		Amounts of protein and fibre respectively.

The provisions of this Part of this Schedule shall apply to any article described therein under whatever name it may be sold or offered for sale and notwithstanding that it contains substance not mentioned in this Part of this Schedule.

The amount, in each case, is to be stated as a definite percentage of the weight of the article, and not as a range of percentages.

The amount of protein meals the amount of nitrogen, other than ammoniacal or nitric nitrogen, if present, multiplied by 6.25.

THIRD SCHEDULE

Sections 1, 2, 20

INGREDIENTS IN FEEDING STUFFS THE PRESENCE OF WHICH
MUST BE DECLARED

(a) Husks, chaff, glumes, shudes, hulls, nutshells or skins of nuts, from any source, whether ground or unground, treated or untreated, when used as separate ingredients or artificial mixtures in the manufacture of feeding stuffs.

Where the kernels naturally associated in seeds with one or other of the above materials are present in a feeding stuff along with the materials with which they are so associated,

regard shall be had to the proportion of the above materials that might reasonably be expected to accompany such kernels, when the seed from which they are derived is in its natural condition, provided that feeding in this condition is regarded as a common practice in the feeding of livestock.

(b) Peat, peat moss, spent hops or sugar cane pith, treated or untreated, ground or otherwise.

(c) Wheat or rye straw, ground or otherwise.

(d) Sawdust or any other form of wood, treated or untreated.

FOURTH SCHEDULE

Section 2

DEFINITIONS IMPLIED ON THE SALE OF ARTICLES UNDER CERTAIN NAMES

PART II: FEEDING STUFFS

<i>Name under which Article Sold</i>	<i>Implied Definition</i>
Alfalfa (lucerne) meal	Alfalfa (lucerne), as grown, dried and ground, to which no other matter has been added.
Barley meal	The meal obtained by grinding barley, as grown, which shall be the whole grain together with only such other substances as may reasonably be expected to have become associated with the grain in the field and which contains not less than 96 per cent pure barley.
Barley meal, Grade II	The meal, other than barley meal as defined above, obtained by grinding barley, as grown, which shall be the whole grain together with only such other substances as may reasonably be expected to have become associated with the grain in the field and which contains not less than 90 per cent pure barley.
Bean meal	The meal obtained by grinding commercially pure beans of the species (1) <i>Vicia Faba</i> (synonym <i>Faba vulgaris</i>) or any of its varieties, commonly known as "horse bean", "field bean" or "broad bean"; or (2) <i>Phaseolus vulgaris</i> , the "true haricot bean" or any of its varieties, white or coloured.
Clover meal	Whole clover, as grown, dried and ground, to which no other matter has been added.
Compound cakes or meals	Cakes or meals (other than molasses feeds and dried molassed beet pulp) consisting of a mixture of one or more of the articles mentioned in Part II of the First Schedule or in Part II of the Second Schedule with any other such article or with any other substance or substances.
Cotton cakes or meals not decorticated	The residue resulting from the removal of oil from commercially pure cotton seed, not decorticated.
Cotton cakes or meals from decorticated or partly decorticated cotton seed	The residue resulting from the removal of oil from commercially pure cotton seed from which the cortex, in whole or in part, has been removed.

FOURTH SCHEDULE. PART II: FEEDING STUFFS *continued*

<i>Name under which Article Sold</i>	<i>Implied Definition</i>
ari meal; durra meal	The meal obtained by grinding commercially pure dari or durra seed.
ied brewery grains	The article produced by drying the residue of malted and unmalted cereals used in brewing, to which no other matter has been added.
ied distillery grains	The article produced by drying the residues from distillery mash-tuns, to which no other matter has been added.
ied grass	Any product which (a) is obtained by artificially drying any of the following:—grass, clover, lucerne, sainfoin, green cereals, or any mixture consisting of any of them, and (b) is otherwise as grown (that is to say including any growths harvested therewith but with no other substance added thereto), and contains not less than 13 per cent protein calculated on the assumption that it contains 10 per cent moisture.
ied grass (maintenance quality)	Dried grass as defined in this Schedule except that it may contain less than 13 per cent but not less than 10 per cent protein calculated on the assumption that it contains 10 per cent moisture.
ied green fodder crops	Any product which (a) is obtained by artificially drying any green crop or crops suitable for use as dried fodder for cattle or poultry, and (b) is otherwise as grown (that is to say, including any growths harvested therewith but with no other substance added thereto), and contains not less than 10 per cent protein calculated on the assumption that it contains 10 per cent moisture, but is not dried grass or dried grass (maintenance quality).
ied green roughage	Any product which contains less than 10 per cent protein calculated on the assumption that it contains 10 per cent moisture, but which in all other respects complies with the definition of dried grass or dried green fodder crops.
ied plain beet pulp	The article produced by drying the sugar beet residue produced in the manufacture of sugar from sugar beet, with or without the addition of molasses, to give less than 10 per cent of sugar.
ied molassed beet pulp	The article produced by drying the sugar beet residue produced in the manufacture of sugar from sugar beet with the addition of molasses, to give 10 per cent or more of sugar.
ied yeast	An article produced by drying yeast or yeast residues, to which no other matter has been added.

FOURTH SCHEDULE. PART II: FEEDING STUFFS *continued*

<i>Name under which Article Sold</i>	<i>Implied Definition</i>
Extracted linseed meal	The residue resulting from the removal of oil from commercially pure linseed by means of a solvent.
Feeding bone flour	The product obtained by grinding commercially pure steamed bone.
Feeding bone meal; ground bone	Commercially pure bone, raw or degreased, which has been ground or crushed.
Feeding dried blood	Blood which has been dried, to which no other matter has been added.
Feeding meat and bone meal	The product, containing not less than 40 per cent of protein and not more than 4 per cent of salt, obtained by drying and grinding animal carcasses or portions thereof (excluding hoof and horn) and bone, to which no other matter has been added, but which may have been preliminarily treated for the removal of fat.
Feeding meat meal	The product, containing not less than 55 per cent of protein and not more than 4 per cent of salt, obtained by drying and grinding animal carcasses or portions thereof (excluding hoof and horn) to which no other matter has been added but which may have been preliminarily treated for the removal of fat.
Fish meal; fish residue meal	A product obtained by drying and grinding or otherwise treating fish or waste of fish, to which no other matter has been added.
Flaked maize	The product obtained by cooking and flaking commercially pure maize or Indian corn, either as grown or from which the germ, in whole or in part, has been removed.
Ground oats	The meal obtained by grinding commercially pure oats, as grown.
Linseed meals or the meals of such cakes	The residue resulting from the removal of oil from commercially pure linseed.
Linseed meal	The meal obtained by grinding or crushing commercially pure linseed.
Locust bean meal	The meal obtained by grinding or crushing commercially pure locust beans.
Maize germ cake or meal	A meal or cake resulting from the grinding of maize germs or from maize germs from which the oil has been removed in whole or in part.
Maize gluten feed	A by-product resulting from the removal of starch and germ from maize, to which no other matter has been added.
Maize meal; Indian meal	The meal obtained by grinding commercially pure maize or Indian corn, as grown.
Malt culms	The rootlets and shoots arising from the screening of malt, to which no other matter has been added.
Molasses feeds	Any mixture (other than dried molassed beet pulp) containing not less than 10 per cent of sugar, of an absorbent material and treacle or molasses.
Nut cakes or meals, including coconut, copra, palm kernel and ground nut cakes and meals	The residue resulting from the removal of oil from commercially pure nut kernels.

FOURTH SCHEDULE. PART II: FEEDING STUFFS *continued*

<i>Name under which Article Sold</i>	<i>Implied Definition</i>
atfeed	The by-product of oatmeal milling consisting of hulls, floury materials, mealy matter, scree dust, all finely ground, and containing not more than 27 per cent of fibre.
ea meal	The meal obtaining by grinding commercially pure peas, as grown, of varieties of "Pisum sativum" or "Pisum arvense".
ape cake or meal	The residue resulting from the removal of oil from commercially pure rape seed.
ice bran; rice meal	The by-product produced in milling shelled rice, to which no other matter has been added.
oya cake or meal	The residue resulting from the removal of oil from commercially pure soya beans.
sugar beet treacle; sugar beet molasses	A concentrated syrup product obtained in the manufacture of sugar from sugar beet, to which no other matter has been added.
sugar cane treacle; sugar cane molasses	A concentrated syrup product obtained in the manufacture of sugar from sugar cane, to which no other matter has been added.
Wheat meal	The meal obtained by grinding commercially pure wheat, as grown.
Wheat offals; millers' offals	A product of wheat separated in the process of milling and containing not more than 4 per cent of vegetable substances, other than wheat, extracted from wheat in the process of cleaning by the maker of the offals in the production of flour.
White fish meal	A product (containing not more than 6 per cent of oil and not more than 4 per cent of salt) obtained by drying and grinding or otherwise treating white fish or waste of white fish, to which no other matter has been added.

In the case of every article mentioned in this Schedule the definition of which includes the expression "commercially pure", it is implied that no other matter may be added.

FIFTH SCHEDULE

Section 7

DELETERIOUS INGREDIENTS IN FEEDING STUFFS

(a) Salts soluble in water, if present in a feeding stuff in proportion likely to be injurious to the health of animals.

(b) All poisonous substances except those naturally present in the material or materials from which the feeding stuff is derived.

(c) Sand, silicious matter or other insoluble mineral matter not naturally associated with ingredients of the feeding stuff which do not fall within the scope of this Schedule, or which, even if naturally so associated, are present in greater proportion than the maximum that may be expected to be due to such natural association.

For the purposes of this paragraph the term "insoluble" shall imply insolubility as determined by a prescribed method; the term "natural association" shall be construed as applying to average commercial samples of the feeding material with which it may be claimed that a particular mineral ingredient is associated.

Bibliography

GENERAL ELEMENTARY TEXTBOOKS

1. C. TYLER. *Animal Nutrition* (Frontiers of Science Series) Chapman & Hall, 1950.
A very compact summary of the fundamental principles. Not intended as a guide to husbandry aspects. Useful list of references to guide further reading.
2. J. C. B. ELLIS. *The Feeding of Farm Livestock*, Crosby Lockwood, 3rd Edition, 1954.
A brief introduction to principles, followed by chapters on the various classes of feedingstuffs and on the practical rationing of farm livestock.
3. E. T. HALNAN & F. H. GARNER. *The Principles and Practice of Feeding Farm Animals*, Longmans, Green, 4th Edition, 1953.
Similar in scope to 2 above.
4. S. J. WATSON. *Feeding of Livestock*, Nelson, 1955.
Similar in scope to 2 and 3 above.
5. L. T. LOWE. *The Student's Handbook to Animal Nutrition*, Littlebury & Co., 1952.
Rather less detailed than 2, 3 and 4, but otherwise covers similar ground.
6. W. M. ASHTON. *Elements of Animal Nutrition*, Griffin, 1950.
See 2, 3 and 4 above.

MORE ADVANCED TEXTBOOKS

7. J. HAMMOND. *Progress in the Physiology of Farm Animals*, Vol. 1, Butterworths, 1954. Vol. 2, 1955 and Vol. 3, 1957.
Sections on ruminant nutrition, pig nutrition, poultry and trace elements, written by authorities on each subject. Vols. 2 and 3 deal with growth, reproduction and milk production. The treatment is more suited to the serious student than to the general reader.
8. D. P. CUTHBERTSON. *Animal Nutrition*, Seale-Hayne Agricultural College, Newton Abbot, 1952.
A small book giving the text of specialist lectures delivered on microbiology and nutrition, level of feeding in relation to production, specific deficiency states, and diet and environment in relation to resistance to disease.
9. J. T. ABRAMS. *Linton's Animal Nutrition & Veterinary Dietetics*, Green, 3rd Edition, 1950.
A general survey of crops, feeding standards and rationing for farm animals. Chapters are also included on feeding rabbits, dogs and cats.
10. E. J. SHEEHY. *Animal Nutrition*, Macmillan, 1955.
Can be recommended for the quality of the practical husbandry in the last two-thirds of the book.

1. E. J. UNDERWOOD. *Trace Elements*, Academic Press, New York, 1956.
A standard text book.
2. *Scientific Principles of Feeding Farm Live Stock*. (Proceedings of a Conference held at Brighton 1958), Farmer & Stock Breeder Publications Ltd.
In this publication experts have attempted to assess the state of knowledge concerning nutrient allowances and margins of safety for farm live stock in the United Kingdom in relation to reproduction, growth, production of meat, milk, wool and eggs.

ADVANCED TEXTBOOKS OF NORTH AMERICAN ORIGIN

3. F. B. MORRISON. *Feeds and Feeding*, Morrison Publication Co., 22nd Edition, 1956.
A monumental book on the subject, both theoretical and practical.
4. T. J. CUNHA. *Swine Feeding and Nutrition*, Interscience Publishers, Ltd., 1957.
Provides information on the latest developments in swine feeding.
5. L. A. MAYNARD AND J. K. LOOSLI. *Animal Nutrition*, McGraw-Hill, 4th Edition, 1956.
An excellent book on the scientific fundamentals of nutrition. Not intended as a guide to husbandry. For advanced students only.
6. E. W. CRAMPTON. *Applied Animal Nutrition*, W. H. Freeman, 1956.
Intended to show how the theoretical quantitative standards can be interpreted into practical rationing. Since the "total digestible nutrients" system is largely adopted and feedingstuffs of typical American nature and composition (e.g., high-protein cereals) are involved, this book is less suitable as a direct aid to British husbandry, but it has a value to those able to translate it into the British idiom.

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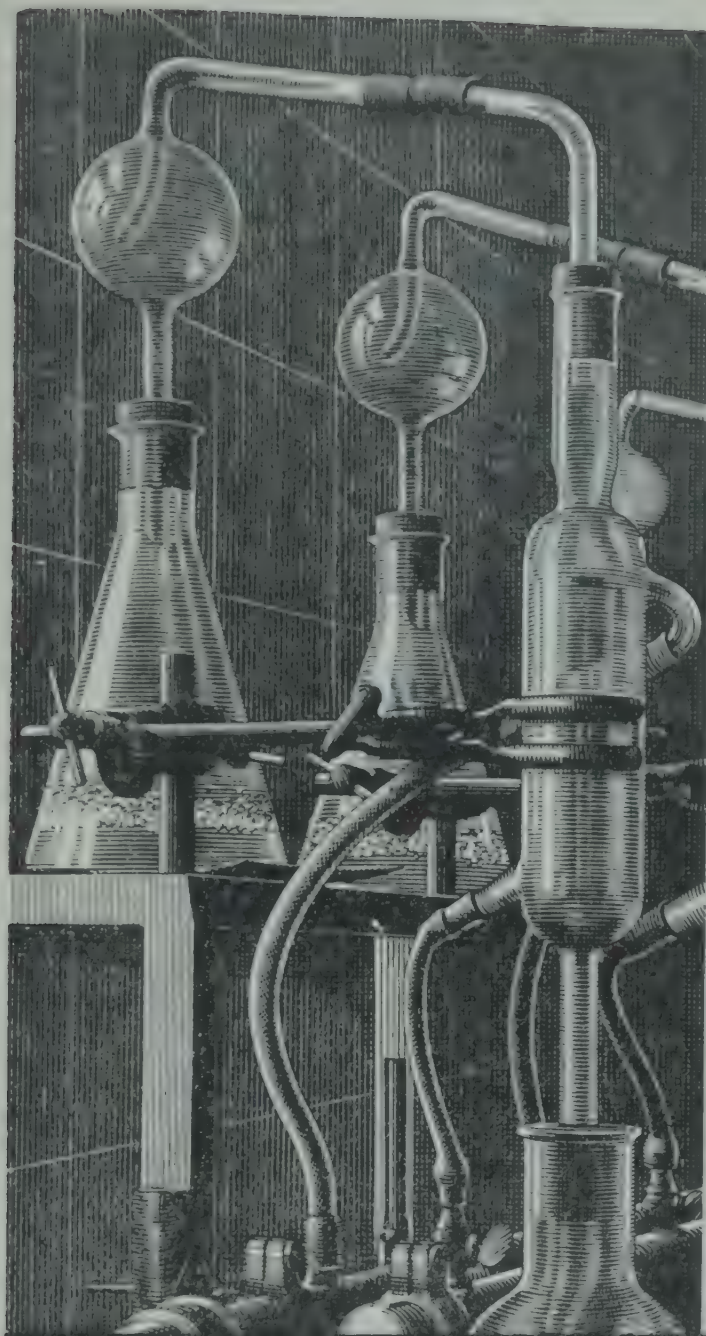
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